INSECT-LIFE

J. H. COMSTOCK

Plate I

EDITION IN COLORS

INSECT LIFE

AN INTRODUCTION TO NATURE-STUDY

AND A GUIDE FOR TEACHERS, STUDENTS, AND OTHERS INTERESTED IN OUT-OF-DOOR LIFE

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WITH FULL-PAGE PLATES FROM LIFE REPRODUCING INSECTS IN NATURAL COLORS, AND WITH MANY ORIGINAL ILLUSTRATIONS ENGRAVED BY ANNA BOTSFORD COMSTOCK, MEMBER OF THE SOCIETY OF AMERICAN WOOD ENGRAVERS : : : : : : : : : : : : : : :

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CONTENTS.

PAGE

INTRODUCTION 1

PART I.

LESSONS IN INSECT LIFE.

CHAPTER

I.—THE PARTS OF AN INSECT 9

II.—THE BEGINNING OF A COLLECTION AND A STUDY OF THE METAMORPHOSES OF INSECTS 22

III.—THE CLASSIFICATION OF INSECTS AND THEIR NEAR RELATIVES 51

IV.—POND LIFE 87

V.—BROOK LIFE 144

VI.—ORCHARD LIFE 166

VII.—FOREST LIFE 186

VIII.—ROADSIDE LIFE 221

PART II.

THE COLLECTION AND PRESERVATION OF SPECIMENS.

I.—THE COLLECTION OF SPECIMENS 284

II.—THE PRESERVATION OF SPECIMENS 294

III.—ON LABELING SPECIMENS AND TAKING NOTES 315

IV.—THE BREEDING OF INSECTS 326

V.—MISCELLANEOUS LISTS 336

LIST OF PLATES

PLATE		TO FACE PAGE
I.	The Cecropia Moth	*Frontispiece*
II.	The Tomato-worm Moth	40
III.	Some Sphinx Moths	80
IV.	Beetles	85
V.	A Pond	87
VI.	A Brook	144
VII.	Dandelions and a Locust	166
VIII.	Forest and Orchard Moths	174
IX.	A Forest Aisle	188
X.	Some Forest Moths	197
XI.	Under-wing Moths	204
XII.	Long-horned Beetles	215
XIII.	Roadside Butterflies	221
XIV.	Tiger-moths	239
XV.	Swallow-tail Butterflies	243
XVI.	Butterflies	246
XVII.	Butterflies	252
XVIII.	Caterpillars	328

INSECT LIFE.

INTRODUCTION.

THIS book was written to meet the demand for a work which will be an aid to teachers of Nature study in the public schools, students in the higher schools, and others interested in outdoor life.

Among all the classes of animals none is more available for study than insects. Their abundance make it easy to obtain specimens; they may be found wherever man can live, and at all seasons. Not only are insects numerous as individuals, but the number of species is far greater than that of all other animals taken together.

The ease with which living insects can be kept in confinement, and the smallness of the expense involved in preserving specimens, add greatly to the availability of insects as subjects for Nature study. No enterprising teacher need hesitate to undertake this study on account of lack of specimens or of apparatus; with a little encouragement the pupils will furnish these, and the teacher need not trouble the school board with requests for an appropriation.

Although at present most adults have been taught to shun insects, most children are easily interested in them. The wonderful transformations of insects, their

beauty, and the high development of their instinctive powers render them attractive subjects of study. Any one can find out something new regarding insect architecture—the ways in which these creatures build nests for themselves or for their young; it is easy to observe remarkable feats of engineering, examples of foresight, wonderful industry, unremitting care of young, tragedies, and even war and slavery.

Insects are no longer thought to be unworthy of serious consideration. We have learned that all life is linked together in such a way that no part of the chain is unimportant. Frequently upon the action of some of these minute beings depends the material success or failure of a large section of our country.

But insects are of interest to us for other reasons than the influence they may have upon our material welfare; the study of them is a fruitful field for intellectual growth. It is not a small matter to be able to view intelligently the facts presented by the insect world, to know something of what is going on around us; and so rich is this field that no one gains more than a mere smattering concerning it.

We know as yet comparatively little about the minute structure of insects; the transformations and habits of the greater number of species have not been studied; and the blood relationship of the various groups of insects is very imperfectly understood. If, therefore, one would learn something of the action of the laws that govern the life and development of organized beings, and at the same time experience the pleasure derived from original investigation, he can not find a better field than is offered

by the study of insects. But it is not necessary that one should have the tastes and leisure required for careful scientific investigation in order to profit by this study. It can be made a recreation, a source of entertainment when we are tired, and a pleasant occupation for our thoughts when we walk.

The desire to know more of the creatures about us is growing rapidly; Nature study is being introduced generally in schools of all grades, and everywhere lovers of out-of-door life are learning to experience the pleasure of a more intimate acquaintance with their surroundings. It is hoped that this will be made easier by this book. Its chief object is to serve as a guide for those who wish to acquire a knowledge of insects from a study of the insects themselves; it is intended to lie open before the observer while the subject of study is examined.

The needs of the beginner in the study of insects, be he old or young, have been kept constantly in mind. The teacher of children who is preparing a lesson, the youth who is studying by himself, and the adult who adds to the pleasure of his outing by learning something new to him—all need to approach Nature by the same path. For this reason an elementary, didactic form of treatment has been adopted, although the book is intended for adults as well as for younger pupils.

It is not expected that the teacher will take a class through the book from beginning to end; for Nature study to be most successful must be varied: each locality and each season will afford different subjects for study.

With young pupils it is best to begin with obser-

vations on living insects. When practicable, excursions into the fields should be made for this purpose. Suggestions as to what insects are most likely to be found in different localities are given in the chapters on Pond Life, Brook Life, Orchard Life, Forest Life, and Roadside Life.

But in most cases it will be necessary to make the observations in the schoolroom. For this a breeding cage or an aquarium will be needed. Directions for making these are given in Chapter IV, pages 326–335.

At first an aquarium will be found more useful than a breeding cage, for the constant movement in a well-stocked aquarium is sure to excite interest. If the pupils are furnished with an insect net (see page 285), they can keep the aquarium supplied with living insects. In the chapters on Pond Life and on Brook Life the more common aquatic insects are described and directions are given for their study.

During the winter, cocoons of the giant silkworms can be collected (see pages 188–197) and kept till the adult moths emerge, affording good material for lessons on the transformations of insects. At the same time, and in early spring, the eggs of the apple-tree tent caterpillar can be found on apple trees and on wild cherry, and later the growth and transformations of the insect observed (see pages 168–171).

At an early period in the course, a home-made breeding cage (see page 327) should be provided; and during the summer months it will be easy to keep it stocked with some of the insects described in the chapters on Orchard Life, Forest Life, and Roadside Life.

While the pupils are becoming familiar with the life of insects, they can be taught something of their structure and of their classification; but with young pupils these subjects should be subordinated to the study of the activities of insects. In the first eight lessons (pages 9–21) the parts of an insect that can be seen without dissection are described. A locust or grasshopper is used as an example, and serves as a type; in later chapters considerable attention is given to the more obvious modifications of structure correlated with the peculiar habits of the insects described. So much of structure as is desirable for the pupils to learn can be taught incidentally while they are observing the habits of the insects.

After the school has been supplied with an aquarium and one or more breeding cages, provision should be made for preserving a collection of insects. Nothing will more surely maintain an interest in Nature study than a growing collection of insects made by the pupils themselves. Do not buy a collection; the specimens that a class can collect in a single summer day will be worth more as a stimulus to personal observation than a purchased collection. In Chapter II (pages 22–50) are given several lessons for beginners on collecting and preserving specimens; and in Part II (pages 284–325) are suggestions for more advanced work in this direction.

In a word, the Nature-study work should not be a fixed, definite course; the most available objects of the locality and season should be selected for study, and these observed from as many points of view as possible. One day observe habits; another, study structure; and later learn something of classification

by putting the specimens in their proper place in a collection.

The Nature study can be made an aid to work in language and in drawing; many suggestions for this are given throughout the book.

With an aquarium, a breeding cage, and a few boxes for preserving specimens, all of which can be procured with little expense, both teacher and pupils will find the Nature-study period the most enjoyable part of the day.

Everything possible should be done to make this study a recreation which the pupils will enjoy outside of school hours. If each has a collection, this will be an easy matter. Do not discourage the pupils by requiring them to memorize abstract statements concerning insects. Let their knowledge of the subject be based on personal observations. The statements in the book are merely to aid the pupils in their study of the specimens; personal observation should be the real source of their information. The development of the habit of ascertaining facts for themselves is one of the greatest benefits the pupils will derive from this study.

In preparing the lessons an effort has been made to combine the verification method and the interrogation method of laboratory work in such a way as to obtain the desirable results of both systems and to give variety to the work. When the former method is used, the teacher will be able in most cases to determine if the pupil has correctly verified the statements made in the text by examining the drawings he is required to make or the account he is asked to write.

It is obvious that, in order properly to direct work of this kind, the teacher should be thoroughly acquainted with the subjects studied by the pupils. The difficulties that have been in the way of the teachers who have tried to obtain a systematic knowledge of insects is doubtless the chief reason that insect life has not been studied more in the public schools. An appreciation of these difficulties led the author and the illustrator of this book to prepare first, for the use of teachers, a comprehensive textbook, by means of which the teacher can easily prepare himself to direct the study of his pupils. This is entitled "A Manual for the Study of Insects."*

In this study, perhaps more than in any other taught in the secondary schools, the pleasure of constantly learning something new can be shared by the teacher with the pupils. The writer has had an unusually broad experience in teaching this subject, but he has never yet taken a class into the field without finding something new to him.

In this connection we wish to urge the importance of perfect sincerity. The teacher should frankly say, "I do not know," when asked a question that he can not answer, and it will be well if he will add, "We will try to find out." Teach the pupils early that any one by intelligent endeavor can add to the sum of knowledge.

While the chief end of this study is the training of the powers of observation and the careful ascertaining of facts in a scientific manner, it seems to us to be well to encourage somewhat an imaginative view

* Published by the Comstock Publishing Company, Ithaca, N. Y.

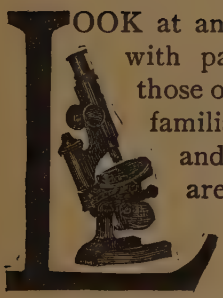
of the subject. For this purpose we have included some poetical references to insects. We believe that the reading of these by the pupils will both stimulate their love of a poetical form of expression and bring them in closer sympathy with the world of life around us.

PART I.

LESSONS IN INSECT LIFE.

CHAPTER I.

THE PARTS OF AN INSECT.



LOOK at an insect and you will find a creature with parts which are very different from those of the animals with which we are more familiar. Although it can see, hear, eat, and walk, its eyes, ears, mouth, and legs are not like the corresponding organs of the higher animals.

It is necessary, therefore, at the beginning of our study of insect life, to learn something of the structure of insects. We will not attempt at first, however, to make a thorough study of insect anatomy, but will merely select one kind of insect, and study the principal divisions of the body as seen from the outside.

Having done this, we will be able to see in our later studies in what ways the parts of other kinds of insects have been modified in form to fit them for their modes of life. Thus, for example, we will find that an insect which catches its prey by running has legs of a different shape than those of an insect that

swims through the water; and an insect that sucks the blood from its victims has a different kind of mouth than one that chews up the leaves of plants.

It is also important that we should know the names of the principal parts of the body of an insect, so that we may understand descriptions of insects, and be able to write descriptions ourselves.

We have selected locusts, or grasshoppers as they are more commonly called, for the subject of these introductory lessons. We have done this because locusts are quite large, and are common in all parts of our country; and, too, the parts of the body in these insects are comparatively simple.

In the course of these lessons the following things will be needed: A supply of locusts,* blank paper and pencils for making notes and drawings, one or more cyanide bottles (see page 286) for killing the specimens collected by the pupils, a lens, cardboard and mucilage for mounting dissections, and scissors. A compound microscope is very desirable, but not absolutely necessary.

* It is best, when practicable, that the pupils should collect these for themselves. But in the case of city schools, or when the work is begun at a season of the year when these insects are not readily found, the teacher should have on hand a supply of locusts preserved in alcohol. These can be collected beforehand or obtained of some dealer in laboratory supplies. The best way to collect them is by sweeping (see page 291) the grass in a dry meadow or pasture in late summer or early autumn. In this way a pint or more of locusts can be collected in a short time. These can be preserved in alcohol in an ordinary glass can, such as is used for preserving fruit. There should be more than enough alcohol to cover the insects, and after they have been in it for twenty-four hours it should be poured off and fresh alcohol substituted. A list of dealers in laboratory supplies is given at the close of this volume for the convenience of those who wish to purchase specimens.

LESSON I.

THE PARTS OF A LOCUST.

Collection of Specimens and a General View of the Body.

1. Collect several locusts or short-horned grasshoppers and bring them to the school. They can be carried in a small box or wide-mouthed bottle. Fig. 1 represents one of these insects.

FIG. 1.—A locust.

2. If living locusts are collected, kill them by leaving them in a cyanide bottle for a half hour or more.

NOTE.—If the pupils can not find living locusts at the time this lesson is taken, preserved specimens will be furnished by the teacher.

3. Count the legs and the wings of the locusts, and make a note of the number of each on a sheet of paper headed *Notes on the Parts of a Locust.*

4. Study the body of the insect and observe that it is composed of three portions: first, the *head;* second, a stout portion to which the legs and wings are attached, the

FIG. 2.—Wasp, with head, thorax, and abdomen separated.

FIG. 3.—Side view of locust with wings removed.

thorax; and, third, the hinder part of the body or *abdomen* (*ab-do'men*).

In a locust the division between the thorax and

the abdomen is not well marked. Fig. 2 represents a wasp with the three regions of the body separated, and in Fig. 3 a locust is represented with its wings removed so as to show the extent of each of these regions.

5. Make a copy on your sheet of notes of the figure of a side view of a locust.

LESSON II.

THE PARTS OF A LOCUST (CONTINUED).

The Head, except the Mouth-parts.

The head is the first of the three regions of the body. It contains the brain of the insect and other important organs; but in these lessons we will study only the outside parts of it. The head bears the antennæ, the eyes, and the mouth-parts.

1. The *antennæ* (*an-ten′næ*) are the two long, slender organs attached to the head in front of the large eyes. Make a drawing of one of them. The singular form of the word antennæ is antenna (an-ten′na).

2. Study the large eyes which are situated one on each side of the head. Examine them with a lens, also with a microscope if you have the use of one. The surface of the eye when much magnified resembles honeycomb in appearance (Fig. 4). Each of the six-sided divisions of the large eye is a complete eye, hence the large eyes are *compound eyes*.

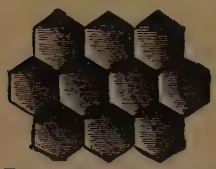


FIG. 4.—Part of compound eye, greatly enlarged.

3. In addition to the two large compound eyes a locust has three *simple eyes*. There is one of these

just in front of the upper part of each compound eye, and the third is in a hollow near the middle of the face of the locust; find each of these.

NOTE.—The simple eyes are usually called the *ocelli* (*o-cel'li*). This term is also applied frequently to the little eyes, or ommatidia, of which the compound eyes are composed; but if nothing is said to indicate that the parts of a compound eye are meant, the term ocelli always refers to the simple eyes. In the same way the term eyes usually refers to the compound eyes alone. The singular form of ocelli is *ocellus* (*o-cel'lus*).

4. Make a drawing of the front side of the head showing the position of the antennæ, the eyes, and the ocelli.

LESSON III.

THE PARTS OF A LOCUST (CONTINUED).

The Mouth-parts.

1. Attached to the lower edge of the front side of the head of the locust is a movable flap; this is the upper lip or *labrum* (*la'brum*). Carefully remove it with a knife and save it.

2. By removing the upper lip there is exposed a pair of horny jaws; these are the *mandibles* (*man'dibles*). The mandibles open sidewise instead of up and down like the jaws of higher animals. Carefully remove the mandibles. This can be done by separating them with a pin, and turning each one sidewise till it breaks from the head. Save the mandibles.

3. By the removal of the mandibles there is exposed a second pair of jaws, which, like the mandibles, open sidewise. These are the *maxillæ* (*max-il'læ*). The singular form of maxillæ is maxilla (max-il'la). The maxillæ, unlike the mandibles, are very complicated organs, each maxilla consisting of sev-

eral parts. Leave the maxillæ attached to the head till later.

4. Remove the head of the locust and pin it with the hinder side uppermost to a piece of cork or block of wood.

5. With the head in this position the flaplike lower lip or *labium* (*la'bi-um*) can be easily seen. Like the maxillæ, the labium consists of several parts.

6. Lift the free end of the labium with a pin and observe the tonguelike organ which arises from the inner side of it, and projects between the maxillæ; this is the *hypopharynx* (*hy-po-phar'ynx*).

FIG. 5.—The mouth-parts of a locust: 8, labrum; 10, mandibles; 11, maxillæ; 11 *d*, maxillary palpi; 12, labium; 12 *d*, labial palpi; 13, hypopharynx.

7. Remove the labium and the hypopharynx and save them.

8. After the removal of the labium it will be easier to remove the maxillæ than before. Remove them and save them.

9. Arrange the mouth-parts on a card as shown in Fig. 5 and gum them in place.

10. The five-jointed appendages of the maxillæ are the *maxillary palpi.* The singular of palpi is palpus.

11. The three-jointed appendages of the lower lip or labium are the *labial palpi.*

Review.—The mouth-parts of a locust consist of an upper lip, the *labrum;* an under lip, the *labium;*

two pairs of jaws, the *mandibles* and the *maxillæ;* and a tonguelike organ, the *hypopharynx*. The jaws open sidewise instead of up and down, as do the jaws of the higher animals. The upper pair of jaws are called the *mandibles;* the lower pair of jaws the *maxillæ*. Each maxilla bears a palpus; these are the *maxillary palpi*. The labium bears a pair of palpi; these are the *labial palpi*.

LESSON IV.

THE PARTS OF A LOCUST (CONTINUED).

The Appendages of the Thorax, the Legs.

The thorax is the middle one of the three regions of the body (see Lesson I and Fig. 3). The appendages of the thorax are three pairs of legs and two pairs of wings. In this lesson we will study the legs.

1. Study carefully one of the fore legs of the locust and observe that it is composed of several parts or segments. Each of these segments of the leg has a distinct name. As these names are often used in descriptions of insects, it is necessary to learn them.

2. The first segment of the legs, the one that is joined to the body, is nearly globular in outline; this is the *coxa* (*cox'a*).

3. The second segment of the leg is much smaller than the coxa; this is the *trochanter* (*tro-chan'ter*).

4. The third segment of the leg is the principal one; this is the *femur* (*fe'mur*). Its name is the same as that of the principal bone in the human leg.

5. The fourth segment of the leg is nearly as long

as the femur, but it is more slender; it is called the *tibia* (*tib'i-a*). This name is the same as the name of the principal bone between the knee and ankle of the human leg.

6. All of the leg of the locust beyond the tibia is the foot or *tarsus* (*tar'sus*). This part consists of three segments in the locust, but the number of segments in the tarsus differs in different kinds of insects.

7. The last segment of the tarsus bears a pair of claws. These are called the *tarsal claws.*

8. Find each of the parts named above in each of the legs of the locust.

9. Make a drawing of one of the fore legs and name the parts.

10. The plurals of the terms are as follows: coxa, coxæ; trochanter, trochanters; femur, femora (fem'-o-ra); tibia, tibiæ; tarsus, tarsi.

LESSON V.

THE PARTS OF A LOCUST (CONTINUED).

The Appendages of the Thorax, the Wings.

1. Remove the two wings of one side, spread them out on a card, and gum them in place.

2. Study the wings and observe that each is composed of a membrane strengthened by a framework of thicker lines. These thickened lines composing the framework are called the *veins of the wings.* The term vein used in this connection is not very appropriate, but as it is in general use it would not be well to attempt to change it.

3. Observe the strong, longitudinal veins, and the numerous smaller cross-veins.

4. The portions of the membrane bounded by the veins are called the cells.

5. Cut a piece about one fourth inch square from one of the wings not removed from the body, mount it on a card, and make a careful drawing of the veins and cells. Label the drawing as follows: *Fragment of the wing of a locust showing the veins and the cells.*

6. Write a description of the wings of a locust; describe first the general features of the wings, and then state how the two wings of one side differ from each other.

LESSON VI.

THE PARTS OF A LOCUST (CONTINUED).

The Thorax.

1. In this lesson we are to study the parts of the thorax, but before beginning this study the pupil should examine the abdomen and observe that the body wall of that region is composed of several ring-like segments.

2. Like the abdomen, the entire body of an insect is made up of a series of segments, but it is not so easy to distinguish the separate segments in the head and thorax as it is in the abdomen.

3. The segments of which the head is composed are grown together so completely that the head appears to consist of a single segment.

4. The thorax consists of three segments, which we will try to distinguish. Observe that the first pair of legs are borne by a ringlike part which can

be separated from the remainder of the thorax. This is the first of the segments of the thorax.

5. Separate the first segment of the thorax from the remainder of this region. Observe that the belly or *ventral* side is small, while the upper or *dorsal* side is large, being composed of the large sunbonnet-shaped piece which is just back of the head.

6. The first segment of the thorax is called the *prothorax* (*pro-tho'rax*).

7. Make a drawing of a side view of the prothorax representing the left side.

8. The portion of the thorax remaining consists of two segments closely grown together. These are the second and third thoracic segments. The second thoracic segment bears the second pair of legs and the first pair of wings; the third thoracic segment bears the third pair of legs and the second pair of wings. Study the specimen and try to make out the limits of these segments.

9. The second or middle thoracic segment is called the *mesothorax* (*mes-o-tho'rax*). The third or last thoracic segment is called the *metathorax* (*met-a-tho'rax*).

10. Remove the wings and make a drawing of the left side of these two segments.

11. Observe that the greater part of each side of these two segments consists of four large, oblique pieces. The first two of these pieces belong to the mesothorax, the last two to the metathorax.

Review.—The body of an insect consists of a series of segments; of these the first three behind the head form the thorax. The three segments of the thorax are called the *prothorax*, the *mesothorax*, and the *metathorax* respectively.

LESSON VII.

THE PARTS OF A LOCUST (CONTINUED).

The Abdomen.

The abdomen is that portion of the body which is behind the thorax. In a locust the thorax and abdomen are so closely connected that it requires careful study to determine where one ends and the other begins.

1. Examine the ventral or belly side of the body and determine which is the first abdominal segment. The front edge of this segment is dovetailed into the metathorax, so that at first sight it appears to be a part of the thorax.

2. Examine the upper or dorsal part of the first abdominal segment; this is widely separated from the ventral part by the cavities for the insertion of the hind legs.

3. Observe the ears; these are situated one on each side of the first abdominal segment. Each is a large opening in the body wall which is closed by a very delicate membrane (see Fig. 3). Locusts differ from other insects in having ears in this position.

4. Examine the seven abdominal segments following the first; each of these is ringlike in form.

5. Find the breathing holes or spiracles. There is a row of them on each side of the body. The first one on each side that is in the abdomen is just in front of the ear. In the seven following abdominal segments there is one on each side of each segment near the lower front corner of the upper part of the segment.

NOTE.—In addition to the abdominal spiracles, there are two pairs of spiracles which belong to the thorax: one of these is situated in the membrane between the prothorax and mesothorax; the other just above and a little back of the insertion of the middle pair of legs. The first of these two pairs is covered by the free margin of the prothorax, which can be cut away with scissors.

6. Examine several specimens of locusts and observe that in some the hind or caudal end of the body tapers to the end and bears four pointed and curved, horny pieces, and that in others this end of the body is terminated by a single, large, hood-shaped plate. Those in which the body ends in four pieces are females; the others are males.

7. The four pieces at the caudal end of the body of the female are for making holes in the ground or in soft wood in which the eggs are laid, and are called the *ovipositor*.

8. In using the ovipositor the insect pushes it into the ground and then spreads the pieces apart; by repeating this operation many times a deep hole is made in which the eggs are laid.

9. Make a drawing of the left side of the abdomen; represent carefully the position of the ear and of the spiracles. Use either a male or female, but state under the drawing which sex it represents.

LESSON VIII.

THE PARTS OF A LOCUST (CONTINUED).

Review.

The following table illustrates the relations of the parts of a locust that have been studied in the preceding lessons. The pupils should learn this table

so that they can write it without referring to the book:

- **Head.**
  - Antennæ.
  - Compound eyes.
  - Simple eyes or ocelli.
  - Mouth-parts.
    - Labrum.
    - Mandibles.
    - Maxillæ and maxillary palpi.
    - Labium and labial palpi.
- **Thorax.**
  - Prothorax and first pair of legs.
  - Mesothorax and
    - second pair of legs.
    - first pair of wings.
  - Metathorax and
    - third pair of legs.
    - second pair of wings.
  - Wing
    - veins.
    - cells.
  - Leg
    - Coxa.
    - Trochanter.
    - Femur.
    - Tibia.
    - Tarsus and claws.
- **Abdomen.**
  - The abdomen bears
    - ears (in locusts only).
    - spiracles.
    - ovipositor.

CHAPTER II.

THE BEGINNING OF A COLLECTION AND A STUDY OF THE METAMORPHOSES OF INSECTS.

THE mere reading of books about natural objects will do but little toward forming an intimate acquaintance with Nature. If one would really *know* about the creatures that are near us wherever we go, he must study them directly, and not depend on what others have said about them.

It is for this reason that these first lessons in Insect Life are based on the study of specimens that the pupils have collected for themselves. It will be far better for the pupils to learn a few things at first hand than to memorize a great mass of information from books.

In most places it is comparatively easy to find insects. The pupils can collect them while going to and from school or during recess; or a class may be excused for an hour or two occasionally to make longer trips, under the direction of one of the older pupils: but, when possible, the teacher should accompany the pupils in their excursions. More insects will be found on warm days when the sun is shining than at other times.

In the case of city schools that are remote from parks or other good collecting fields, excursions into country places can be made on Saturdays, and the specimens collected on such an excursion can be kept for study till the following Monday. Much more progress in attaining *real knowledge* will be made in this way than by daily recitations based on a study of a book about insects.

With a little effort living insects can be kept in breeding cages or aquaria, so that the specimens collected on a single excursion may serve for daily observations for a long time.

Each pupil should be encouraged to make a permanent collection for himself. With such a collection there is little danger of his losing his interest in the subject; and the facts that he has learned will be remembered more easily. Moreover, the making of additions to a collection and the frequent rearranging of it will be a source of great pleasure and instruction.

If for any reason it is impracticable for the pupils to make private collections, a collection should be made for the school. If the specimens in such a collection are labeled with the names of the collectors, the pupils will be stimulated to make additions to it. And if, as soon as the older pupils have learned to handle specimens carefully, each is appointed curator of some group of insects, a personal interest in the collection will be stimulated, and each will acquire a more thorough knowledge of the group collected than he would otherwise.

The group assigned to a student may be some order or family of insects, or an artificial group based on habits. Some experience with the local con-

ditions in each school will be necessary for the teacher to be able to select the more available groups.

Even when the pupils make private collections it will be well to have each one, after he has become familiar with the different orders, select some one of them as his specialty, and study that one more thoroughly. In this way he will be forced to do more careful collecting in order to add to his collection constantly, and he will thus learn more about the habits of the insects collected.

Before beginning the work the teacher should decide what apparatus is to be used, and make provision for obtaining that part of it which the pupils are not to make for themselves, so that the work shall not be delayed by lack of material.

Although there are many things that are desirable for carrying on this work, much can be accomplished with very little material and that which is inexpensive. The following lists will aid the teacher in deciding what to get:—

Necessary Supplies for Pupils.

Cyanide bottles. See page 286.
Pins. See page 295.
Empty cigar-boxes. See page 306.
Cork or pith. See page 309.

Additional Supplies desirable for Pupils.

Insect nets. See page 285.
Glass-topped cases. See page 306.
Coddington lenses. See below.
Vials.
Alcohol.

Desirable Supplies for the School.

Cabinet for insect cases. See page 294.
Pliers or pinning forceps. See page 299.
Cases, pins, vials, and alcohol.
Microscope. See below.
Supplies for mounting microscopic objects. See page 300.

At least the teacher should possess a lens. Of the cheaper lenses the form known as the Coddington lenses I have found to be the best. These are commonly kept by stationers or jewelers. They can also be procured of any dealer in optical instruments. See list of dealers at the end of this volume.

If a microscope be procured for the school, care should be taken to get one provided with what is known as the society screw, so that objectives of any of the more prominent makers can be used on it. If the funds at the disposal of the school will only admit of the purchase of a microscope with a single objective, a three-fourths-inch objective will be found as useful as any for entomological work, and perhaps later a one-fifth-inch objective or others can be added. Price lists of microscopes will be furnished by dealers in optical instruments. Most dealers make discounts from their list prices when furnishing schools.

In preparing the above suggestions we have tried to keep in mind the needs and the ability of supplying these needs of both teachers in the smaller schools, where there may be no funds to spend for apparatus, and of teachers in the larger schools, where even costly apparatus can be purchased.

LESSON IX.

PREPARATION FOR A COLLECTING TRIP.

Having learned something about the structure of a locust, which was taken as a typical insect, we are ready to begin the study of other insects. In doing this we will first learn how to collect and preserve specimens; after that we will study the classification of insects and the life histories of some of them.

The forms of insects are numberless, and their ways are as varied as are their forms. As we walk over the fields they spring up before us or scurry away through the grass. Some fly lazily here and there; others dart back and forth with the rapidity of thought. We crush them under foot by a careless step; we find them on every shrub and tree; and the streams and ponds are peopled by them.

Let us approach their study with kindly feelings, bent on learning what we can concerning them and their ways, and putting aside the false notion that many of us have been taught that these creatures are to be despised. The great majority of them can be regarded as our friends, for they are of service to us; others, while not actually beneficial, do us no appreciable harm; a few, and they are only a few compared with the great number that make up the insect world, interfere with our happiness. These we are forced to fight; but the combat is one of self-defense and not a war against an enemy that harms us maliciously.

In making a collection for study it will be necessary for us to kill specimens; but we will do this as

humanely as possible, and will not destroy more than we need for our work.

The objects of this lesson are two: first, the suggesting of a proper spirit in which to take up this work; and, second, the getting ready for our first field trip, so that when the time comes to start there will be no delay.

The most important thing to carry with you into the field is a good pair of eyes. Without these but little will be accomplished.

Of the various kinds of collecting apparatus the most important is a cyanide bottle. Each pupil, if possible, should have one of these. On page 286 will be found directions for making them.

In addition to a cyanide bottle it will be well if each one has an insect net, although much can be done without a net. See page 285 for a description of an insect net.

No other apparatus is needed for the first field trip, but it will be well if some provision be made at once for preserving the insects that you are going to collect. The following are the more important things needed for this:

1. An insect case or empty cigar-boxes. Read what is said on pages 306 to 310 regarding these, and note especially what is said on page 310 regarding the use of corn pith for lining cigar-boxes.

2. A supply of insect pins or, if these can not be obtained, a paper of ordinary pins. Read what is said on this subject on pages 295 to 299.

LESSON X.

THE FIRST COLLECTING TRIP.

Material needed for the Excursion.—"A sharp pair of eyes," a cyanide bottle, and an insect net if you have one.

Where to look for Specimens.—On flowers and leaves, on the surface of the ground, under stones and pieces of wood lying on the ground, in rotten stumps, and under the bark of decaying logs and trees.

What to collect.—We plan to study all kinds of insects and also some animals that are not true insects, but are closely related to them. It will be best, however, on this first excursion to collect only *winged* insects. Other forms may be collected and studied later in the course.

Suggestions.—Do not leave your cyanide bottle open unnecessarily, for if you do it will lose its strength in a short time. With proper care a cyanide bottle will last several months.

Do not hold your face near the open cyanide bottle so as to breathe the fumes that escape from it. With ordinary care there is no danger in the use of a cyanide bottle.

You can take bees and wasps from flowers without danger of being stung by shutting them into the bottle with the cork. Take the bottle in one hand and the cork in the other, and bring the two together quickly, one on each side of the insect.

The insects collected can be left in the cyanide bottles or on damp sand in a jar or tight box till

the following day. If the excursion is made on Saturday the insects can be kept soft in this way till Monday.

FIG. 6.—Poison ivy. (Note that the leaflets are in threes, and that each has only a single midrib.)

If a cyanide bottle is wet inside it should be wiped out and a piece of blotting paper placed in it. But if the dampness is due to the dissolving of the cyanide it is better to put enough dry plaster of Paris

FIG. 7.—Virginia creeper. (Note that the leaflets are in fives.)

into the bottle to absorb the liquid; sprinkle the plaster of Paris carefully on top of the layer of cement in the bottom of the bottle, so that the whole shall form one solid layer.

To the Teacher.—If poison ivy or poison oak abounds in the region where the pupils are to col-

lect, the plant should be made known to them. They should also be able to distinguish between

FIG. 8.—Clematis. (Note that the leaflets are in threes, like the poison ivy, but each leaflet has several midribs.)

poison ivy and the harmless Virginia creeper and clematis. See Figs. 6, 7, and 8.*

LESSON XI.

ON MOUNTING SPECIMENS.

1. Take the specimens that were collected on the first collecting trip, and which have been kept moist either by being left in the cyanide bottle or in a closed vessel upon damp sand, and spread them out before you. If the directions were followed, they are all winged.

2. Select one of the larger specimens and observe

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* The writer, who is extremely susceptible to the poison of poison oak and poison ivy, has experienced great relief when poisoned by bathing the affected parts frequently with a lotion made of one part tincture of grindelia and four parts water. Prompt and frequent application of this lotion will prevent the appearance of the pustules characteristic of this disease; if the application be not made soon enough for this, the injury can be kept from spreading by a thorough and *persistent* use of the lotion.

that, as with the locust, the body consists of three main parts—the *head*, the *thorax*, and the *abdomen*.

3. In pinning insects most specimens should be pinned through the middle of the thorax. Read the section on pinning insects on page 297.

4. Pin four or five of the larger specimens in this way, leaving about one fourth of the length of the pin above the back of the insect. If insect pins be used, avoid using the smaller sizes, as they are easily bent. Insects that are too small to be pinned with No. 3 Kläger pins should be mounted on cards as described later.

5. Ascertain if you have any beetles in your collection. Beetles have a pair of wing-covers in the place of the front wings. These wing-covers are thick and horny, and meet in a straight line down the back of the insect, forming a hard case, beneath which the hind wings are folded. Fig. 9 represents a beetle.

FIG. 9.—A beetle.

6. Separate the beetles in your collection from the other specimens.

7. In pinning beetles the pin should be put through the right wing-cover at a point about one fourth the length of the wing-cover from its base (see Fig. 10).

8. Pin all the beetles in your collection that are large enough to be pinned.

9. Pin any other winged insects you have that are large enough to be pinned, remembering that except in case of beetles the insects should be pinned through the middle of the thorax.

FIG. 10.

10. If there remain some insects that are too small to be pinned, they should be mounted on cardboard points, as described on page 298.

11. Count the legs on each specimen in your collection. (It is supposed that you have only winged specimens.) How many legs do winged insects have?

The shrilling locust slowly sheathes
His dagger voice, and creeps away
Beneath the brooding leaves where breathes
The zephyr of the dying day:
One naked star has waded through
The purple shallows of the night,
And faltering as falls the dew
It drips its misty light.
O'er garden blooms,
On tides of musk,
The beetle booms adown the glooms
And bumps along the dusk.

The katydid is rasping at
The silence from the tangled broom:
On drunken wings the flitting bat
Goes staggering athwart the gloom:
The toadstool bulges through the weeds;
And lavishly to left and right
The fireflies, like golden seeds,
Are sown about the night.

O'er slumb'rous blooms,
On floods of musk,
The beetle booms adown the glooms
And bumps along the dusk.
*James Whitcomb Riley.**

LESSON XII.

THE SECOND COLLECTING TRIP.

1. Review carefully the directions on page 28.

2. On this excursion the pupils should collect any true insects—that is, those having only six feet—that they may find; but the especial object of the excur-

FIG. 11.—Nymph of *Melanoplus*, first stage. (After Emerton.)

FIG. 12.—Nymph of *Melanoplus*, second stage. (After Emerton.)

FIG. 13.—Nymph of *Melanoplus*, third stage. (After Emerton.)

FIG. 14.—Nymph of *Melanoplus*, fourth stage. (After Emerton.)

sion is to get a set of specimens illustrating the growth of either crickets or locusts or bugs. Select whichever of these is most common, and get as com-

* From Old-fashioned Roses, by permission of the Bowen-Merrill Co.

plete a series as possible representing the changes from the very young insect without any wings, through the different stages of wing-growth up to the adult insect.

The accompanying figures (Figs. 11–16) represent the transformations of a common locust. Note that

FIG. 15.—Nymph of *Melanoplus*, fifth stage. (After Emerton.)

FIG. 16.—*Melanoplus*, adult.

the figures of the younger stages are enlarged. The hair line represents in each case the length of the insect.

LESSON XIII.

INCOMPLETE METAMORPHOSIS.

Nearly all insects undergo great changes in form while getting their growth. Thus, caterpillars in time become butterflies or millers; grubs when fully developed are beetles; and maggots are the young of two-winged flies.

In the case of butterflies, millers, beetles, and two-winged flies, the fully developed insects bear but little resemblance in form to the young. It would be difficult to find two adult insects that differ more in form than do a butterfly and the caterpillar from which it was developed. But in the case of certain other insects, the changes undergone during the life of the insect are not nearly so great as with

these. Thus the young locust resembles the adult in form to a great extent, except that it lacks wings; and the same thing is true of crickets, bugs, and many other insects.

Those insects which, like butterflies, millers, beetles, and flies, undergo a complete change of form while getting their growth are said to undergo a *complete metamorphosis.*

Insects which, like locusts, crickets, and bugs, do not change greatly in form except by the gradual growth of wings are said to undergo an *incomplete metamorphosis.*

Let us study more carefully the changes of an insect with an incomplete metamorphosis.

1. Pin the specimens that were collected on the last excursion. If some are too small to pin, mount them on cardboard points.

2. Select those that were collected to illustrate the changes in form from the very young insect without any wings through the different stages of wing-growth up to the adult insect.

3. Determine how many stages of growth are represented by these, and place together the specimens illustrating each stage. The young of insects that undergo an incomplete metamorphosis are termed *nymphs.*

4. Make an outline drawing of the thorax and wings, when they are present, of each stage. Draw either the dorsal or a side view, whichever will show best the development of the wings.

LESSON XIV.

MOLTING.

1. Take a locust that has been killed by being placed in a cyanide bottle or in alcohol and cut the abdomen in two, near the middle of it.

2. Observe that the hard parts of the body are on the outside, and that there is no internal skeleton, as in our own bodies.

This fact makes necessary a peculiar feature in the growth of insects and of the other animals that are closely related to them. The body of an insect is inclosed in a firm case, which, as it does not increase in size, becomes too tight for the insect as the insect grows. To meet this difficulty the outer hard layer of the skin is shed. The inner soft layer of the skin then stretches so as to accommodate the increased size of the insect; later this soft skin, which is now on the outside, becomes hard, so as to serve as a protection to the insect. In time this skin also becomes too tight, but another soft skin has been formed beneath it, and the hard skin can be shed like the other.

FIG. 17. — The cast skin of a nymph of a dragon-fly.

This process of shedding the skin is termed *molting*.

Insects differ greatly as to the number of times that they molt; some pass through only three or

four molts, while others shed their skin twenty times or more.

It is at the time of molting that changes in the form of the body take place.

Fig. 17 represents the cast skin of a nymph of a dragon-fly.

LESSON XV.

OBSERVATION OF INCOMPLETE METAMORPHOSIS.

1. Collect a considerable number—fifteen or twenty or more—of nymphs of locusts or crickets, and place them in a breeding cage. See page 327 for directions for making inexpensive breeding cages.

2. Put a sod of growing grass in the cage for the insects to feed upon, and replace it with a fresh one when necessary.

3. Endeavor to rear the nymphs, and make notes on their changes.

4. Examine the cage daily, and when cast skins are found, study them and preserve specimens for your collection.

5. Preserve a specimen of each of the nymph stages, and label it with the date on which it was taken.

6. Observe that, although the changes between the different nymph stages are slight, the change between the last nymph stage and the adult is a marked one, there being a great increase in the size of the wings at this time.

THE GRASSHOPPER AND THE CRICKET.

Green little vaulter in the sunny grass,
Catching your heart up at the feel of June,
Sole voice that's heard amid the lazy noon,
When even the bees lag at the summoning brass;
And you, warm little housekeeper, who class
With those who think the candles come too soon,
Loving the fire, and with your tricksome tune
Nick the glad silent moments as they pass;
Oh, sweet and tiny cousins, that belong
One to the fields, the other to the hearth,
Both have your sunshine; both, though small, are strong
At your clear hearts; and both were sent on earth
To sing in thoughtful ears this natural song:
Indoors and out, summer and winter—Mirth.

Leigh Hunt.

LESSON XVI.

OBSERVATION OF COMPLETE METAMORPHOSIS AND DEFINITION OF TERMS.

And what's a butterfly? At best,
He's but a caterpillar, drest.—*John Gay.*

1. Collect some caterpillars, and, keeping them alive, put them in a breeding cage to rear. See pages 327 to 330 for directions for making breeding cages.

2. Keep the caterpillars supplied with food, giving them the same kind of plant as that on which they were found, and keep only one kind of caterpillar in a single breeding cage. Most of the common hairy caterpillars found running over the surface of the ground will feed on grass and many other plants, but other caterpillars will starve if not fed on their proper food plant.

NOTE.—Among the more available kinds of caterpillars for use in this lesson are the following: The common green cabbage-worms; the green worm, ringed with black and spotted with yellow, that eats the leaves of caraway; and the large yellow and black one found on milkweed. The transformations of each of these can be observed in a comparatively short time if the study begins early enough in the season. The autumn broods of the first two pass the winter in the pupa state.

3. Begin a series of notes on each kind of caterpillar under observation, giving each a number and numbering the notes to correspond. (See Part II, Chapter III.) Begin each note with the date on which it was made. Record everything that you observe regarding the habits and transformations of

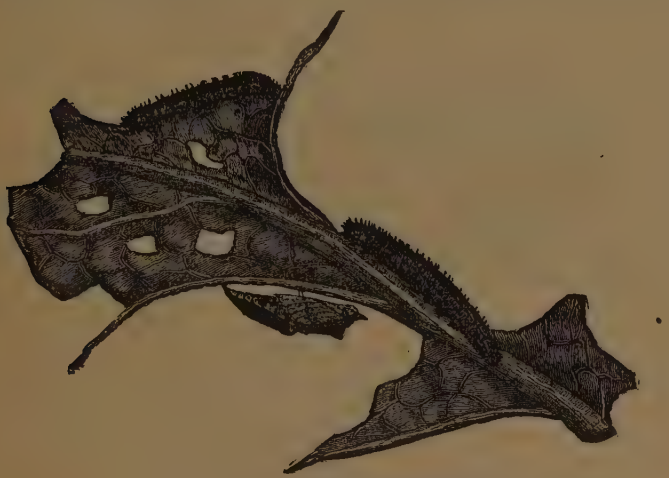

FIG. 18.—Larvæ and pupa of a butterfly.

the insects. Try to observe the molting of the insects and each of the transformations.

4. All caterpillars hatch from eggs. If you succeed in rearing adult insects and will keep some of them caged for a time you may be able to get eggs.

But many insects will not lay in confinement. They are more apt to lay in confinement if caged with a growing food plant of the larva.

5. Caterpillars and the corresponding stage of other insects with a complete metamorphosis are called *larvæ*. The singular form of this word is *larva*.

6. When a larva is full grown it molts its skin and appears in a very different form. This third stage (the egg being the first and the larva the second) is called the *pupa*. The plural of pupa is *pupæ*. In Fig. 18 there are represented two larvæ on the upper edge of a fragment of a leaf and a pupa suspended from the lower edge. The pupæ of butterflies are sometimes called chrysalids.*

FIG. 19.—A large cocoon within a rolled leaf.

7. Some larvæ before changing to the pupa state spin about the body a silken case within which the pupa state is passed. Such a case is called a *cocoon*. Sometimes a leaf is fastened about the cocoon (Fig. 19); and some hairy caterpillars make their cocoons largely of their own hair, fastening it together with a thin layer of silk.

8. Following the pupa state is the *adult* or *imago* state.

* There are two forms of this word: first, chrysalid, with the plural chrysalids; and, second, chrysalis, with the plural chrysalides. The singular form of the second and the plural form of the first are in more common use.

PLATE II.—THE TOMATO-WORM MOTH.

Phlegethontius celus.

Plate II

LESSON XVII.

REVIEW OF TERMS USED IN DESCRIBING THE METAMORPHOSES OF INSECTS.

Kinds of Metamorphosis.	Names of Stages.
I. Development without metamorphosis. This has not been described in these lessons, and it occurs only in a single order of insects, the Thysanura (see page 63).	*Egg.* *Immature insect.* *Adult.*
II. Incomplete metamorphosis.	*Egg.* *Nymph* (several stages). *Adult* or *imago.*
III. Complete metamorphosis.	*Egg.* *Larva.* *Pupa.* (The pupa is sometimes inclosed in a *cocoon.*) *Adult* or *imago.*

LESSON XVIII.

BEETLES OR COLEOPTERA (Co-le-op'te-ra).

While the pupils are observing the development of the insects in their breeding cages, which will probably require a long time, the work of making a collection can be continued.

1. Collect as many kinds of beetles as you can and mount them as directed in Lesson XI. Beetles can be found under stones and pieces of wood lying on the ground, under the loose bark of dead trees, logs, and stumps, and on the foliage of plants.

2. The beetles, of which there are many thousand kinds, constitute what is termed by naturalists an *Order*. There are several orders of insects; the one composed of beetles is named the Coleoptera. This

name is from two Greek words: one, *koleos*, meaning a sheath, and the other, *ptera*, meaning wings. It refers to the fact that in this order in place of the front wings there are two horny sheaths which cover the hind wings.

3. Prepare a label like that given below.

Order Coleoptera (Co-le-op'te-ra).

The Beetles.

4. Pin this label into the upper left-hand corner of your case, and arrange your beetles below the label in rows extending from left to right, putting only one kind of beetle in a row.

5. As you collect more beetles place them with these, putting each kind in its proper row.

6. Select one of the larger beetles in your collection and make a drawing representing the dorsal view of it.

LESSON XIX.

THE ORDER COLEOPTERA (CONTINUED).

1. Carry a small cyanide bottle in your pocket, and, whenever you have an opportunity, collect any beetles that you can find, and add them to your collection.

2. Observe that in each kind of beetle the wings are always of the same size. The wings of these insects are not gradually developed as they are with locusts, crickets, and bugs; but the young of beetles

are grubs which undergo a complete metamorphosis in the course of their development.

3. Select one of the larger beetles, and examine its wing-covers, or *elytra*, as they are called. Remove them, and note their structure. How do the elytra of beetles differ from the front wings of locusts?

4. Study the hind wings. How does the folding of the hind wings of a beetle differ from that of the hind wings of a locust?

5. Mount the elytra and hind wings of the beetle on a card.

6. Study the mouth-parts of the beetle, dissecting them out, and mounting them on a card as was done with the mouth-parts of a locust in Lesson III. Label each of the mouth-parts.

7. Remove some of the upper rows of beetles in your case so as to make room for the two cards just prepared, and place the cards immediately below the label for the order. Then rearrange the beetles below the cards.

8. We have now observed the more important characteristics of the order Coleoptera or beetles, which are as follows:

Order Coleoptera.— The members of this order have a pair of horny wing-covers, called elytra, which meet in a straight line down the back, and beneath which there is a single pair of membranous wings. The mouth-parts are formed for biting. The metamorphosis is complete.

LESSON XX.

TRANSFORMATIONS OF A BEETLE.

1. Find a potato field infested with the Colorado potato-beetle. Fig. 20 represents the adult of this insect.

2. If this species is not in your collection, collect some of the adult beetles for it.

FIG. 20.

3. Search for the larva of this potato-beetle. It is a thick, plump grub, strongly arched above, and of a pale yellow color, with two rows of black spots on each side.

4. Search also for the eggs of this insect. These are yellow in color and are laid in clusters on the leaves of the potato.

5. Take the eggs and larva to the school alive and put them in a breeding cage. Keep the larvæ supplied with fresh potato leaves and watch their development, keeping notes on it. Put a few of the eggs and larvæ in alcohol and preserve them in your collection.

6. When full grown, the larvæ go into the ground to transform; there should on this account be a layer of soil in the bottom of the cage.

7. After the larvæ have gone into the ground to transform, some of the cocoons should be dug up and preserved in the collection.

8. When the beetles begin to emerge from the ground, dig up some of the cocoons and remove pupæ from them for the collection.

9. Arrange the specimens of this species in your

collection in the following order, eggs, larvæ, cocoons, pupæ, adults, and label each group.

LESSON XXI.

A COLLECTING TRIP.

1. Review carefully the directions and suggestions given for the first collecting trip in Lesson X.

2. The special object of this trip is to learn to collect insects by sweeping grass and beating the foliage of herbs and shrubs with an insect net. See page 290 for directions for the use of insect nets.

Great care should be taken to procure the specimens in as good condition as possible. Empty your net frequently, so that the specimens shall not be injured by the sweeping or beating.

LESSON XXII.

MOUNTING OF SPECIMENS.

If the sweeping and beating of the last trip were successful, there will be considerable work to be done in mounting specimens. Before doing this read pages 297 to 299, and then endeavor to mount your specimens in as good condition as possible and preserve them for future study.

LESSON XXIII.

ON COLLECTING BUTTERFLIES.

Owing to the dustlike covering with which butterflies and moths, or millers, are clothed, and which

is easily injured, it is necessary to make a special study of the methods of collecting these insects; for if the specimens are not handled properly, they will be of very little use for study. We will first study the collecting of butterflies.

1. For collecting butterflies an insect net and a collecting box are necessary. The pupils doubtless have insect nets before this lesson is reached; the collecting boxes can be made of empty cigar boxes, as described on page 287.

2. In addition to the net and collecting box a bottle of chloroform with a brush fitted into the cork (Fig. 21) is very desirable, although not absolutely necessary.

3. It is seldom best to attempt to run down a butterfly and catch it on the wing. Follow the insect quietly until it alights, and catch it while at rest.

FIG. 21.

4. The removal of the insect from the net should be done with very great care, for here lies the greatest danger of injury to the specimen.

If the butterfly is a small one, it can be taken from the net by placing the mouth of an open cyanide bottle over it; in this way touching the specimen with the fingers is avoided.

If the specimen is too large for this, the net should be held in such a way that the insect can not flutter and thus injure its wings. Try to have it come to rest with its wings folded over its back, for the lower side of the wings are not so easily injured as is the upper side. Then take the fold of the net containing the butterfly between the thumb and finger

of one hand and pinch the thorax of the insect. This can be done in such a way as to kill the insect at once without crushing the specimen. It can then be removed from the net and pinned and placed into the collecting box.

If the collector has a bottle of chloroform and brush, as soon as the insect is at rest in a fold of the net it can be killed by wetting its thorax with chloroform. This is done by putting the wet brush on the net where it rests against the thorax of the insect. The butterfly can then be removed and pinned into the collecting box.

5. Read paragraph on folded papers for butterflies, page 287.

6. Go into the field and collect some butterflies. Try to secure them in perfect condition rather than to try to get a large number.

7. If you have time to spread the butterflies when you return from the field, pass at once to the next lesson; but if not, put the specimens on damp sand in a tightly closed jar or box and leave them till the following day. See paragraph on relaxing insects, page 305.

LESSON XXIV.

ON SPREADING BUTTERFLIES.

Read the directions for making spreading boards and for spreading insects on pages 303 to 305, and then spread the butterflies that you have collected.

LESSON XXV.

THE STRUCTURE OF BUTTERFLIES.

1. Take a butterfly that has just been killed or one that has been relaxed in a damping jar, and pin it so that it can be handled without rubbing the colors from the wings.

2. Examine the compound eyes with a lens or microscope, and make a drawing illustrating the structure of the surface; only a small portion of one eye need be represented, but show this greatly enlarged.

3. Observe on the lower side of the head two forward-projecting organs. These are the feelers of the lower lip or labial palpi.

4. Observe an organ that is coiled up between the labial palpi. If the butterfly has been recently killed or is thoroughly relaxed, this organ can be straightened out by using a pin. It is the sucking tube by means of which the insect extracts nectar from flowers. It is composed of two parallel parts closely united, but with a channel between them through which the nectar is sucked. These two parts are the maxillæ, which have become greatly developed and modified to fit them for sucking. The other mouth-parts, except the labial palpi, are poorly developed.

5. Remove the head and gum it with the maxillæ uncoiled to a card which is large enough to receive the two wings of one side also.

6. Remove the two wings of one side and gum them to the card with the head.

7. Study the clothing of the wings. It is necessary to use at least a lens for this; if there is a microscope in the school it should be used for this study. It will be found that the dust covering the wings and body is composed of scales, which are of regular form; and that in butterflies these scales are arranged in regular order upon the wings. Fig. 22 represents part of a wing of a butterfly greatly magnified. In the upper part of the figure the membrane of the wing is represented with the scales removed.

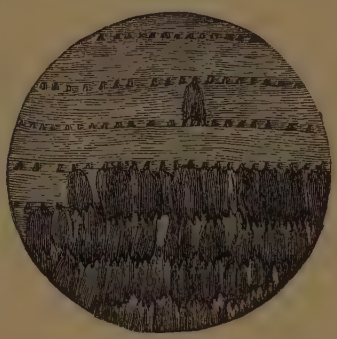

FIG. 22.—Part of wing of butterfly, greatly magnified.

8. The butterflies, together with the moths, or millers, and the skippers, which are insects that resemble butterflies, constitute an order which is named the Lepidoptera. This name is from two Greek words: *lepis*, a scale, and *pteron*, a wing. It refers to the scaly covering of the wings and body.

9. Make a copy of the following label, and fasten it in your collection above the specimens of Lepidoptera:

Order Lepidoptera (Lep-i-dop'te-ra).

The Butterflies, Skippers, and Moths.

10. Place the card bearing the head and wings of a butterfly immediately below this label.

LESSON XXVI.

ON COLLECTING MOTHS.

1. The fact that moths, or millers as they are often called, do not fold their wings above the body like butterflies makes it impracticable to kill specimens by pinching the thorax. Very large specimens can be killed by chloroform, as described in Lesson XXIII; but most specimens should be taken from the net by placing the mouth of an open cyanide bottle over them. Never touch a specimen with the fingers if it can be avoided.

2. Do not carry moths in a cyanide bottle with other insects. It is best to have a separate bottle for Lepidoptera, for they are liable to be injured by rubbing against other insects; and the specimens of other insects will be soiled by the scales from the butterflies or moths.

3. Many moths can be collected in the fields by day, but much larger numbers can be taken at night at lights or at sweetened baits. Read the sections on sugaring and on collecting at lights on pages 292 to 293.

4. Collect as many kinds of moths as possible, taking especial pains to get the specimens in good condition.

5. Carefully spread one or more specimens of each kind; other specimens may be simply pinned and left till winter, when they can be relaxed and spread.

CHAPTER III.

THE CLASSIFICATION OF INSECTS AND THEIR NEAR RELATIVES.

IN the course of the lessons in the preceding chapter, a beginning was made in the classification of insects. The subject can now be taken up in a more systematic manner. It is not, however, the purpose of this book to carry the classification of insects further than to the orders, although in the chapters following this a few easily recognized families will be studied. It is believed that it is better for the pupils that are beginning this study to devote the greater part of their time to the study of the structure and habits of insects; later, the classification can be carried farther with the aid of more advanced manuals written for that purpose.

The collector of insects is sure to meet many small animals that, although not true insects, are closely allied to them. It is important, therefore, that the characteristics of these near relatives of insects should be pointed out, which we will briefly do, before discussing the orders of insects.

The Classes of the Branch Arthropoda.

In the study of the parts of a locust (see Lesson VI) it was learned that the body of an insect is composed of a series of more or less similar rings or segments joined together. This fact is also true of the bodies of certain other animals that are not insects; thus, if the body of a scorpion, a centipede, or a lobster be examined, it will be found to resemble that of an insect in this respect. There is another characteristic in which these animals resemble insects—namely, some of the segments of the body bear jointed legs.

All the animals possessing these two characteristics are classed together as the branch *Arthropoda* (*Ar-throp'o-da*) of the animal kingdom, the term branch being applied to each of the principal divisions of the animal kingdom.

A similar segmented form of the body is characteristic of worms, but these are distinguished from the Arthropoda by the absence of legs. It should be remembered that many animals commonly called worms, as the tomato-worm, apple-worm, etc., are not true worms, but are the larvæ of insects. The angle worm is the most familiar example of a true worm.

The principal divisions of a branch of the animal kingdom are called classes. The more common representatives of the branch Arthropoda are distributed among four classes. These are the Crustacea, the Arachnida, the Myriapoda, and the Hexapoda. The last of these comprises the insects, the first three the near relatives of insects.

The following table will enable the student to distinguish the classes of the Arthropoda.*

TABLE OF CLASSES OF THE ARTHROPODA.

A. With two pairs of antennæ and at least five pairs of legs. Aquatic animals breathing by gills. Page 53.....CRUSTACEA.

AA. With one pair of antennæ or with none. Air-breathing animals. The number of legs varies from six to many.

B. Without antennæ and with four pairs of legs, although the maxillary palpi are often leglike in form, making the animal appear to have five pairs of legs. Page 55.....ARACHNIDA.

BB. With antennæ.

C. With more than three pairs of legs; and without wings. Page 57.....MYRIAPODA.

CC. With only three pairs of legs, and usually with wings in the adult state. Page 58.....HEXAPODA.

Class CRUSTACEA (Crus-ta'ce-a).

The Crustaceans (*Crus-ta'ce-ans*).

The most familiar illustrations of the Crustacea are the crayfishes, the lobsters, the shrimps, and the

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* The following is the method of using the analytical tables given in this book: Read carefully the statement of characteristics given opposite A and AA respectively, and by examining the animal to be classified determine which is true of this animal. This will indicate in which division of the table the name of the group to which the animal belongs is to be looked for. If this division of the table is subdivided, pass to B and BB (also to BBB if it occurs) *in this division* and determine in a like manner under which the animal belongs. Continue in this way, passing to the letters C, D, E, etc., in regular order till the name of the group is reached. Then turn to the page indicated and read the description of the group given there, comparing the specimens with the description. It should be borne in mind that an analytical table is merely an aid to the determination of groups. As the groups that we recognize are not always sharply limited in nature, we can not expect to be able in every case to find characters that will serve to distinctly separate them in a table. Therefore when a student has determined by the aid of a key to what

crabs. Crayfishes (Fig. 23) abound in our brooks, and are often improperly called crabs. The lobsters, the shrimps, and the true crabs live in salt water.

FIG. 23.—A crayfish.

The Crustacea are distinguished from all other Arthropods by having two pairs of antennæ and by their mode of respiration, being the only ones that breathe by true gills. Many insects live in water and are furnished with gill-like organs, but these are tracheal gills. True gills are for the purification of blood, while tracheal gills are for the purification of the air contained in the air vessels or tracheæ of an insect. The former contains a large number of blood vessels, the latter a large number of air vessels.

FIG. 24.—Crustacea: *a*, *Cypris*; *b*, *Cyclops*; *c*, *Daphnia*.

FIG. 25. A sow-bug.

There are minute Crustacea common in ponds and streams. Three of the more abundant of these

group a species seems to belong, he should verify this determination by a study of the characters of that group given in the detailed discussion of it.

are shown greatly enlarged in Fig. 24; they frequently occur in aquaria in which aquatic plants are growing. The sow-bugs (Fig. 25) are also Crustacea. They live about water-soaked wood; with these only one pair of antennæ are well developed.

Class Arachnida (A-rach'ni-da).
The Arachnids (*A-rach'nids*).

To this class belong the spiders, scorpions, harvestmen, mites, and certain other less common forms. These animals differ from the other classes of the branch Arthropoda in having no antennæ. They have four pairs of legs fitted for walking, and many of them have very large maxillary palpi, which resemble legs. The head and thorax are closely united, forming a region which is called the *cephalothorax* (*ceph-a-lo-tho'rax*). These characteristics are easily seen in spiders (Fig. 26).

Fig. 26.—A spider.

The most common representatives of the class Arachnida are the spiders. These are extremely interesting animals on account of the high development of their instinctive powers. An account of the habits of some of the common species is given in the chapter on Roadside Life.

The harvestmen (Fig. 27) are also abundant in most parts of our country. These feed on small in-

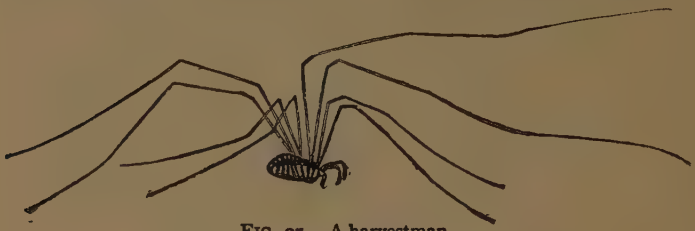


FIG. 27.—A harvestman.

sects, especially aphids, and are perfectly harmless. They are sometimes called "grandfather graybeards."

Scorpions (Fig. 28) are common in the southern portions of the United States, but are not found in the North. They feed upon spiders and large insects, which they seize with the large pincers of their palpi, and sting to death with a poison sting, which is at the hind end of the body.

FIG. 28.—A scorpion.

The mites are mostly very small. They differ from other

FIG. 29.—An itch mite: a, from below; b, from above.

Arachnids in having the abdomen fused with the cephalothorax (Fig. 29). Certain velvety red species

often attract attention on account of their red color, and other species are often found parasitic on insects. The annoying parasites that are known as ticks (Fig. 30), and which are common in the warmer parts of our country, are mites. The sheep-tick, however, is a wingless fly.

FIG. 30. — The cattle-tick, female.

Class MYRIAPODA (Myr-i-ap'o-da).
The Myriapods (*Myr'i-a-pods*).

This class includes the centipedes and the millipedes, both of which are commonly called thousand-legged worms. The members of this class have a distinct head which bears a single pair of antennæ. The body is long, and consists of similar segments, which are not grouped into regions, and each segment of the body bears one or two pairs of legs.

FIG. 31.—A centipede.

The centipedes (Fig. 31) have only a single pair of legs to each segment. Representatives of many species of these are common. The poison glands open through the claws of the first pair of legs, which are bent forward so as to act with the mouth-parts. The centipedes feed on insects.

FIG. 32.—A millipede.

The millipedes (Fig. 32) differ from the centipedes in having two pairs of legs on each of the body segments except the first three. The millipedes, as a

rule, live in damp places, and feed on decaying vegetable matter. They are harmless, except that occasionally they feed upon growing plants.

Class Hexapoda (Hex-ap'o-da).
The Insects.

Insects differ from the other classes of the Arthropoda in having only three pairs of legs, and usually in having wings in the adult state. They have a single pair of antennæ, and the segments of the body are grouped into three regions: head, thorax, and abdomen.

The name Hexapoda is from two Greek words: *hex*, six, and *pous*, foot. Numerous examples of insects are figured in the following portions of this chapter.

THE ORDERS OF THE CLASS HEXAPODA.

The class Hexapoda, or insects, is divided into nineteen orders. In our Manual for the Study of Insects these orders and the families of which they are composed are discussed in detail, but in these first lessons we can only briefly refer to each order. The following table is taken from the Manual. This table of orders is merely intended to aid the pupil in determining to which of the orders a specimen that he is examining belongs. No effort has been made to indicate in the table the relation of the orders to each other.

TABLE FOR DETERMINING THE ORDERS OF HEXAPODA.*

(*This table includes only adult insects.*)

A. Wingless or with rudimentary wings.

B. Mandibles and maxillæ retracted within the cavity of the head so that only their apices are visible. Page 63.....THYSANURA.

BB. Mandibles and maxillæ more or less prominent and fitted for biting. (See BBB also.)

C. Head with long, trunklike beak. (*Boreus.*) Page 78. MECOPTERA.

CC. Head not prolonged into a trunk.

D. Louselike insects of small size; body less than one sixth inch in length.

E. Antennæ with not more than five segments. (Bird-lice.) Page 69.....MALLOPHAGA.

EE. Antennæ with many segments. (Book-lice.) Page 68. CORRODENTIA.

DD. Insects of various forms, but not louselike, and, except in the case of some ants, with the body more than one sixth inch in length.

E. Abdomen with short, conical, compressed, many-jointed caudal appendages. (*Cockroaches.*) Page 70...ORTHOPTERA.

EE. Abdomen without jointed caudal appendages.

F. Legs fitted for jumping. (*Wingless locusts, grasshoppers, and crickets.*) Page 70.....ORTHOPTERA.

FF. Legs fitted for running.

G. Abdomen broadly joined to the thorax.

H. Body linear. (*Walking-sticks.*) Page 70. ORTHOPTERA.

HH. Body white and somewhat antlike in form. (*Termes.*) Page 67.....ISOPTERA.

HHH. Body neither linear nor antlike in form. (*Wingless firefly et al.*) Page 85.....COLEOPTERA.

GG. Base of abdomen strongly constricted. (*Ants et al.*). Page 85.....HYMENOPTERA.

BBB. Mouth-parts formed for sucking.

C. Small abnormal insects in which the body is either scalelike or gall-like in form, or grublike and clothed with wax. The waxy

* See note at bottom of page 53.

covering may be in the form of powder, of large tufts or plates, of a continuous layer or of a thin scale, beneath which the insect lives. (*Coccidæ*.) Page 75.....HEMIPTERA.

CC. Body more or less covered with minute scales, or with thick long hairs. Prothorax not free (i. e., closely united with the mesothorax). Mouth-parts usually consisting of a long "tongue" rolled beneath the head. Page 80.....LEPIDOPTERA.

CCC. Body naked, or with isolated or bristlelike hairs.

D. Prothorax not well developed, inconspicuous or invisible from above. Tarsi five-jointed. Mouth-parts developed into an unjointed trunk; palpi present. Page 83.....DIPTERA.

DD. Prothorax well developed.

E. Body strongly compressed; tarsi five-jointed. (*Fleas*.) Page 84.....SIPHONAPTERA.

EE. Body not compressed; tarsi one-, two-, or three-jointed.

F. Last joint of tarsi bladderlike or hooflike at the tip; mouth parts forming a triangular, unjointed beak; palpi present. Page 74.....PHYSOPODA.

FF. Last joint of tarsi not bladderlike, and furnished with one or two claws; mouth parts forming a slender, usually jointed beak; palpi apparently wanting. Page 75. HEMIPTERA.

AA. Winged. (The wing-covers, *elytra*, of beetles and of earwigs are counted as wings in this table.)

B. With two wings.

C. Wings horny, leathery, or parchmentlike.

D. Mouth-parts formed for sucking. Wings leathery, shortened, or membranous at the tip. Page 75.....HEMIPTERA.

DD. Mouth-parts formed for biting. Jaws distinct.

E. Wings horny, without veins. Hind legs not fitted for jumping. Page 85.....COLEOPTERA.

EE. Wings parchmentlike, with a network of veins. Hind legs fitted for jumping. Page 70.....ORTHOPTERA.

CC. Wings membranous.

D. Abdomen with caudal filaments. Mouth-parts rudimentary.

E. Halteres wanting. Page 64.....EPHEMERIDA.

EE. Halteres present (males of *Coccidæ*). Page 75. HEMIPTERA.

DD. Abdomen without caudal filaments. Halteres in place of second wings. Mouth-parts formed for sucking. Page 83. DIPTERA.

BB. With four wings.
C. The two pairs of wings unlike in structure.
D. Front wings leathery at base, and membranous at tip, often overlapping. Mouth-parts formed for sucking. Page 75. HEMIPTERA.
DD. Front wings of same texture throughout.
E. Front wings horny or leathery, being veinless wing covers. (*Elytra.*)
F. Abdomen with caudal appendages in form of movable forceps. Page 69.....EUPLEXOPTERA.
FF. Abdomen without forceplike appendages. Page 85. COLEOPTERA.
EE. Front wings leathery or parchmentlike, with a network of veins.
F. Under wings not folded. Mouth-parts formed for sucking. Page 75.....HEMIPTERA.
FF. Under wings folded lengthwise. Mouth-parts formed for biting. Page 70.....ORTHOPTERA.
CC. The two pairs of wings similar, membranous.
D. Last joint of tarsi bladderlike or hooflike at the tip. Page 74. PHYSOPODA.
DD. Last joint of tarsi not bladderlike.
E. Wings entirely or for the greater part clothed with scales. Mouth-parts formed for sucking. Page 80....LEPIDOPTERA.
EE. Wings naked, transparent, or thinly clothed with hairs.
F. Mouth-parts arising from the hinder part of the lower surface of the head, and consisting of bristlelike organs inclosed in a jointed sheath. (*Homoptera.*) Page 75. HEMIPTERA.
FF. Mouth-parts in normal position. Mandibles not bristlelike.
G. Wings net-veined, with many veins and cross-veins.
H. Tarsi consisting of less than five segments.
I. Antennæ inconspicuous, awl-shaped, short, and slender.
J. First and second pairs of wings nearly the same length; tarsi three-jointed. Page 65...ODONATA.
JJ. Second pair of wings either small or wanting; tarsi four-jointed. Page 64.....EPHEMERIDA.
II. Antennæ usually conspicuous, setiform, filiform clavate, capitate, or pectinate.

J. Tarsi two- or three-jointed.
K. Second pair of wings the smaller. Page 68.
CORRODENTIA.
KK. Second pair of wings broader, or at least of the same size as the first pair. Page 66.
PLECOPTERA.
JJ. Tarsi four-jointed; wings equal. Page 67.
ISOPTERA.

HH. Tarsi consisting of five segments.
I. Abdomen with setiform, many-jointed anal filaments. (*Certain May-flies.*) Page 64..EPHEMERIDA.
II. Abdomen without many-jointed anal filaments.
J. Head prolonged into a trunklike beak. Page 78.
MECOPTERA.
JJ. Head not prolonged into a beak. Page 77.
NEUROPTERA.

GG. Wings with branching veins and comparatively few cross veins, or veinless.
H. Tarsi two- or three-jointed.
I. Posterior wings smaller than the anterior. Page 68.
CORRODENTIA.
II. Posterior wings as large as or larger than the anterior ones. (*Certain stone-flies.*) Page 66.
PLECOPTERA.

HH. Tarsi four- or five-jointed.
I. Abdomen with setiform, many-jointed anal filaments. (*Certain May-flies.*) Page 64.
EPHEMERIDA.
II. Abdomen without many-jointed anal filaments.
J. Prothorax horny. First wings larger than the second, naked or imperceptibly hairy. Second wings without, or with few, usually simple, veins. Jaws (mandibles) well developed. Palpi small. Page 85.....HYMENOPTERA.
JJ. Prothorax membranous or, at the most, parchmentlike. Second wings as large as or larger than the first, folded lengthwise, with many branching veins. First wings naked or thinly clothed with hair. Jaws (mandibles) inconspicuous. Palpi long. Mothlike insects. Page 79.
TRICHOPTERA.

List of Orders of the Hexapoda.

THYSANURA.	HEMIPTERA.
EPHEMERIDA.	NEUROPTERA.
ODONATA.	MECOPTERA.
PLECOPTERA.	TRICHOPTERA.
ISOPTERA.	LEPIDOPTERA.
CORRODENTIA.	DIPTERA.
MALLOPHAGA.	SIPHONAPTERA.
EUPLEXOPTERA.	COLEOPTERA.
ORTHOPTERA	HYMENOPTERA.

PHYSOPODA.

Order THYSANURA (Thys-a-nu'ra).

Bristletails, Springtails, Fish-moths, and others.

The members of this order are wingless insects which undergo no metamorphosis, the larval form being retained by the adult. The mandibles and maxillæ are retracted within the cavity of the head, so that only their tips are visible; they have, however, some freedom of motion, and can be used for biting and chewing soft substances. True compound eyes are rarely present; but in some genera there is a group of simple eyes on each side of the head. The abdomen is sometimes furnished with rudimentary legs.

FIG. 33. — The fish-moth.

A familiar example of this order is the fish-moth (Fig. 33), which often does damage to starched clothing, bookbindings, and sometimes loosens wall paper by eating out the paste. The hair line at the left of the figure indicates the length of the insect.

The fish-moth is one of the bristletails, which are

so called on account of the bristles at the hind end of the body. Fig. 34 represents one of the springtails.

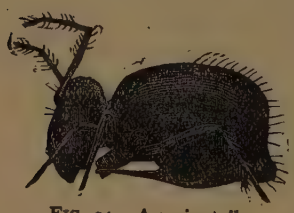


FIG. 34.—A springtail.

In these insects there is a taillike organ, which is bent under the insect when it is at rest, and by which it can leap several feet. Springtails are abundant in damp places, among decaying vegetation; but they are commonly overlooked on account of their minute size.

The name Thysanura is from two Greek words: *thysanos*, a tassel, and *oura*, the tail.

Order EPHEMERIDA (Eph-e-mer'i-da).
The May-flies.

The members of this order have delicate membranous wings with a fine network of veins; the fore wings are large and the hind wings are much smaller, or wanting. The mouth-parts are rudimentary. The met morphosis is incomplete.

The name of this order is from the Greek word *ephemeros*, lasting but a day. It was given to these insects on account of the shortness of their lives after reaching the adult state. Fig. 35 represents a common species. Work on May-flies is outlined in the chapter on Pond Life.

FIG. 35.—A May-fly.

Order ODONATA (Od-o-na'ta).
The Dragon-flies and Damsel-flies.

The members of this order have four membranous wings which are finely netted with veins; the hind wings

FIG. 36.—A dragon-fly.

are as large or larger than the fore wings, and each wing has near the middle of its front margin a jointlike structure —the nodus. The mouth-parts are formed for biting. The metamorphosis is incomplete.

The name of this order is evidently from the Greek word *odons*, a tooth; but the reason for applying it to these insects is obscure. It may refer to the tusklike form of the abdomen.

Fig. 36 represents a dragon-fly, and Fig. 37 a damsel-fly Work on these insects is outlined in the chapter on Pond Life.

FIG. 37.—A damsel-fly.

Order PLECOPTERA (Ple-cop'te-ra).
The Stone-flies.

The members of this order have four membranous wings, with comparatively few or with many cross-veins; the hind wings are much larger than the fore wings, and are folded in plaits and lie upon the abdomen when at rest. The mouth-parts are of the biting type of structure, but are frequently poorly developed. The metamorphosis is incomplete.

The name of this order is from two Greek words: *plecos*, plaited, and *pteron*, a wing. It refers to the way in which the hind wings are

FIG. 38.—A stone-fly.

FIG. 39.—A nymph of a stone-fly.

folded when at rest. Fig. 38 represents one of the larger members of this order with the wings of one side spread, and Fig. 39 represents a nymph. Work on these insects is outlined in the chapter on Brook Life.

Order Isoptera (I-sop'te-ra).

The Termites or White-ants.

The members of this order are social insects. Each species consists of several distinct castes, of which only the "kings" and the "queens" are winged. These have four long, narrow wings, which are somewhat leathery in structure, and which are furnished with numerous but more or less indistinct veins. The two pairs of wings are similar in form and structure, and are laid flat upon the back when not in use. The mouth-parts are formed for biting. The metamorphosis is incomplete.

Fig. 40.
A worker.

The termites are commonly called white-ants on account of their light color and the fact that they live in large communities like ants. They are, however, not at all closely related to the true ants. They can be distinguished from ants at a glance by the absence of a slender waist between the thorax and abdomen (Fig. 40).

Fig. 41.
A soldier.

The termites that occur in the United States are usually found in old logs and stumps, or in the ground under stones. During the greater part of the year only the workers (Fig. 40) and the soldiers (Fig. 41) are found in the nest. But during early summer the winged forms, the newly developed kings and

Fig. 42.
A queen.

queens, also occur. A mature, egg-laying queen is presumably present in each nest; but this form of our common species has not yet been found. Fig. 42 represents an egg-laying queen of an African species.

The name of this order is from two Greek words: *isos*, equal, and *pteron*, a wing. It refers to the fact that the two pairs of wings are similar in form and structure.

Order CORRODENTIA (Cor-ro-den'ti-a).
The Psocids (Psoc'ids) and the Book-lice.

The winged members of this order have four membranous wings, with the veins prominent, but with comparatively few cross-veins; the fore wings are larger than the hind wings; and both pairs when not in use are placed rooflike over the body, being almost vertical, and not folded in plaits. The mouth-parts are formed for biting. The metamorphosis is incomplete.

The winged members of this order feed upon lichens and are found on the trunks of trees and on fences; they often occur in swarms. Fig. 43 represents a common form with its wings spread.

FIG. 43.—A psocid.

FIG. 44.—A book-louse.

The most familiar representative of the wingless forms is the book-louse (Fig. 44). This is a minute insect which occurs between the leaves of old books and on papered walls of houses.

The name of this order is from the Latin word *corrodere*, to gnaw, and refers to the gnawing habits of these insects.

Order MALLOPHAGA (Mal-loph'a-ga).
The Bird-lice.

The members of this order are wingless parasitic insects, with biting mouth-parts. The metamorphosis is incomplete.

The bird-lice are common on poultry and other birds. They differ from the true lice in having biting mouth-parts, and in feeding upon either feathers, hair, or the skin, while the true lice have sucking mouth-parts and feed upon blood. Fig. 45 represents a species which infests poultry.

FIG. 45. A bird-louse.

The name of the order is from two Greek words: *mallos*, wool, and *phagein*, to eat. Although some species infest sheep and goats, feeding upon their wool, by far the greater number live among the feathers of birds.

Order EUPLEXOPTERA (Eu-plex-op'te-ra).
The Earwigs.

The members of this order have apparently four wings; the first pair of which are leathery, very small, without veins, and when at rest meet in a straight line on the back; the second pair are large, with radiating veins, and when at rest are folded both lengthwise and cross-wise. The mouth-parts are formed for biting. The caudal end of the body is furnished with a pair of appendages which resemble forceps. The metamorphosis is incomplete.

These are long and narrow insects, resembling

rove beetles in the form of the body and in the shortness of the wing covers, but easily distinguished by having a pair of forceps at the end of the body (Fig. 46). The common name, earwig, has reference to a widely spread fancy that these insects creep into the ears of sleeping persons.

FIG. 46.—An earwig.

The earwigs are rare in the northeastern United States, but are more often found in the South and on the Pacific coast. In Europe they are common, and are often troublesome pests, feeding upon the corollas of flowers, fruits, and other vegetable substances.

The name of the order is from three Greek words: *eu*, well, *pleko*, to fold, and *pteron*, wing. It refers to the unusual folding of the hind wings.

Order ORTHOPTERA (Or-thop'te-ra).

Cockroaches, Crickets, Grasshoppers, and Others.

The members of this order have four wings: the first pair are thickened, and overlap when at rest; the second pair are thinner, and are folded in plaits like a fan. The mouth-parts are formed for biting. The metamorphosis is incomplete.

The name of the order is from two Greek words: *orthos*, straight, and *pteron*, a wing. It refers to the longitudinal folding of the hind wings.

This order includes only six families, and as they are among our most common insects we will briefly refer to each of them.

Family BLATTIDÆ (Blat'ti-dæ).—The body is oval when seen from above, and is very flat; the three pairs of legs are similar in form; the insects run rapidly. They are commonly known as cockroaches. Some are winged (Fig. 47), others are wingless (Fig. 48).

FIG. 47. The Croton-bug.

FIG. 48. A wingless cockroach.

Family MANTIDÆ (Man'ti-dæ).—The prothorax is very long and slender; the first pair of legs are very different from the others and are fitted for grasping. These insects feed on other insects, which they seize with their fore legs. The suppliant attitude which they assume while lying in wait for

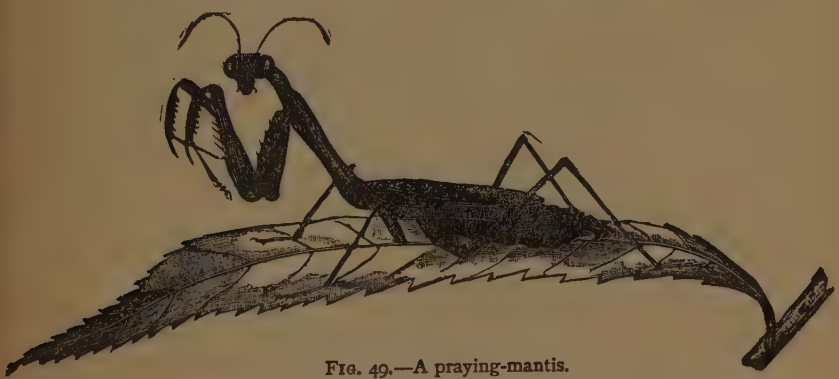


FIG. 49.—A praying-mantis.

their prey (Fig. 49) has given them the name of praying mantes, the name of the typical genus being *Mantis*.

Family PHASMIDÆ (Phas'mi-dæ).—The body is very long and slender; the three pairs of legs are

similar in form, and are also very long and slender; the insects walk slowly. This family includes the well-known walking sticks (Fig. 50).

FIG. 50.—A walking-stick.

Family ACRIDIDÆ (A-crid'-i-dæ).—There are three families of this order in which the hind legs are very much

FIG. 51.—A locust.

stouter or very much longer, or both stouter and longer, than the other pairs, being fitted for jumping. This is the first of these three families. In this family the antennæ are shorter than the

FIG. 52.—A locust.

body. The ovipositor is short and composed of four separate plates. The tarsi are three-jointed. The members of the family are known as locusts or short-horned grasshoppers (Figs. 51 and 52).

Family LOCUSTIDÆ (Lo-cus'ti-dæ).—This is the second of the three families of jumping Orthoptera.

In this family the antennæ are very slender and longer than the body. (This is also true of crickets.) The ovipositor is sword-shaped. The tarsi are four-jointed. The family as a whole are called the true grasshoppers or the long-horned grasshoppers. Some of the smaller species (Fig. 53) are known as meadow-grasshoppers, and a few of the larger species are called katydids (Fig. 54). It should be observed that, owing to an unfortunate application of names,

FIG. 53.—A meadow-grasshopper.

FIG. 54.—The angular-winged katydid and its eggs.

the locusts do not belong to the Locustidæ, but to the Acrididæ.

Family GRYLLIDÆ (Gryl'li-dæ).—This is the last of the three families of jumping Orthoptera. With these insects the antennæ, like those of the long-horned grasshoppers, are very slender and longer than the body, except in the mole-crickets. The ovipositor is spear-shaped when exerted. The tarsi are three-jointed. The members of this family are known as crickets (Figs. 55 and 56).

FIG. 55.—A cricket.

FIG. 56.—A cricket.

Order PHYSOPODA (Phy-sop'o-da).

Thrips.

The members of this order have four wings; these are similar in form, long, narrow, membranous, not folded, with but few or no veins, and only rarely with cross-veins; they are fringed with long hairs, and are laid horizontally along the back when at rest. The metamorphosis is incomplete. The mouth-parts are probably used chiefly for sucking; they are intermediate in form between those of the sucking and those of the biting insects. The tarsi are one- or two-jointed and bladderlike at tip.

The name Physopoda is from two Greek

words: *physao*, to blow up, and *pous*, a foot. It refers to the curious bladderlike feet of these insects.

The species of thrips are very minute insects. Fig. 57 represents one of them greatly enlarged, with the wings of one side spread. They can be easily found by pulling to pieces the blossoms of clover or daisies. Some species are black, others are light brown. The wingless nymphs of our common black species are bright red.

FIG. 57.—A thrips.

Order HEMIPTERA (He-mip'te-ra).

Bugs, Lice, Aphids, and others.

The winged members of this order have four wings; in one suborder the first pair of wings are thickened at the base, with thinner extremities which overlap on the back; in another suborder the first pair of wings are of the same thickness throughout, and usually slope at the sides of the body. The mouth-parts are formed for sucking. The metamorphosis is incomplete.

The name Hemiptera is from two Greek words: *hemi*, half, and *pteron*, a wing. It was suggested by the form of the first pair of wings in the true bugs. Here the basal half of these organs is thickened somewhat like the wing covers of beetles, only the terminal half being winglike. The second pair of wings are membranous, and when at rest are folded beneath the first pair.

Within this order are grouped insects that differ greatly in form and appearance. These are dis-

tributed among three suborders, which can be separated by the following table:

A. Wingless Hemiptera, parasitic upon man and other mammals, with a fleshy unjointed beak.....II. PARASITICA.
AA. Hemiptera with or without wings, but with a jointed beak.
B. First pair of wings thickened at the base, with thinner extremities, which overlap on the back; beak arising from the front part of the head (Fig. 58). .....I. HETEROPTERA.
BB. Wings of the same thickness throughout, and usually sloping at the sides of the body; beak arising from the hinder part of the lower side of the head (Fig. 59).....III. HOMOPTERA.

Suborder HETEROPTERA (Het-e-rop'te-ra). This suborder includes the true bugs, of which the squash-bug (Fig. 60) and the common stink-bugs (Fig. 61) are well-known examples. Several families of this suborder are discussed in the chapters on Pond Life and on Brook Life.

FIG. 58.—Head of an heteropterous insect.

FIG. 59.—Head of an homopterous insect.

FIG. 60.—The squash-bug.

FIG. 61.—A stink-bug.

Suborder PARASITA (Par-a-si'ta).—This suborder is represented in the United States by only one family, the Pediculidæ (Ped-i-cu'li-dæ). This family comprises the true lice (Fig. 62), which differ from the bird lice of the order Mallophaga in having sucking mouth parts. The true lice live on the skin of mammals

FIG. 62. A louse.

and suck their blood. There are several species that infest man.

Suborder HOMOPTERA (Ho-mop'te-ra).—The Homoptera includes insects of widely diversified form, but which agree, however, in having the wings when present of the same thickness throughout, and usually sloping roof-like at the sides of the body when at rest, and in having the beak arise from the hinder part of the lower side of the head (Fig. 59).

FIG. 63.—A cicada.

Among the more common representatives of this suborder are the cicadas (Fig. 63) and the spittle-insects and the tree-hoppers, described in the chapter on Roadside Life. The common plant-lice, or aphids, and the scale-bugs are also members of this suborder.

Order NEUROPTERA (Neu-rop'te-ra).
The Dobson, Aphis-lions, Ant-lions, and Others.

The members of this order have four wings; these are membranous and furnished with numerous veins, and usually with many cross-veins. The head is not prolonged into a beak. The mouth-parts are formed for biting. The metamorphosis is complete.

The name of this order is from two Greek words: *neuron*, a nerve, and *pteron*, a wing. It refers to the numerous nerves, or veins as they are more commonly called, with which the wings are furnished.

When the name Neuroptera was first used it was

applied to a much larger group of insects than now, a group which has since been divided into many orders. So that now, while the name expresses a character which is true of the order, it is also true of many others.*

One of the more conspicuous members of the order is *Polystœchotes punctatus* (*Pol-ys-tœch'o-tes punc-ta'tus*), which is represented by Fig. 64. To this order also belong *Corydalis* (see page 153) and the *Aphis-lions* (see page 178).

FIG. 64.—*Polystœchotes punctatus.*

Order MECOPTERA (Me-cop'te-ra).

The Scorpion-flies and Others.

The members of this order have four wings; these are membranous and furnished with numerous veins. The head is prolonged into a beak, at the end of which biting mouth-parts are situated. The metamorphosis is complete.

This is a small order composed of very remarkable insects. The most striking character common to all is the shape of the head, which is prolonged into a beak with jaws at the end (Fig. 65). The name *Mecoptera* is from two Greek words: *mecos*, length, and *pteron*, a wing.

FIG. 65.—Head of a scorpion-fly.

The members of the genus *Panorpa* (*Pa-nor'pa*) (Fig. 66) are called scorpion-

* The Neuroptera of the older entomologists included the following orders: Thysanura, Ephemerida, Odonata, Plecoptera, Isoptera, Corrodentia, Mallophaga, Neuroptera, Mecoptera, and Trichoptera.

flies on account of the peculiar form of the caudal part of the abdomen of the male (Fig. 67). This at first sight suggests the corresponding part of a scorpion, but in reality the two are very different.

FIG. 66.—A scorpion-fly.

Very closely allied to the scorpion-flies are the insects of the genus *Bittacus* (*Bit'-ta-cus*). These insects have long narrow wings, long legs, and a slender abdomen. They resemble crane-flies very closely when on the wing. In this genus the caudal appendages of the male are not enlarged as in *Panorpa*.

FIG. 67. Tail of a scorpion-fly.

The species of the genus *Boreus* (*Bo're-us*) are remarkable for occurring on snow in the winter in our Northern States. In this genus the females are wingless, while the males have rudimentary wings.

Order TRICHOPTERA (Tri-chop'te-ra).

The Caddice-flies or Caddice-worms.

The members of this order have four wings; these are membranous, furnished with numerous longitudinal veins, but with only few cross-veins, and are more or less densely clothed with hairs. The mouth-parts are rudimentary. The metamorphosis is complete.

FIG. 68.—A caddice-fly.

FIG. 69.—A caddice-worm.

This order is composed of the caddice-flies and caddice-worms (Figs. 68 and 69), which are discussed

in the chapter on Brook Life. The name of the order is from two Greek words: *thrix*, a hair, *pteron*, a wing. It refers to the fact that the wings are clothed with hair.

Order LEPIDOPTERA (Lep-i-dop'te-ra).

The Moths, or Millers, the Skippers, and the Butterflies.

The members of this order have four wings; these are membranous and covered with overlapping scales. The mouth-parts are formed for sucking. The metamorphosis is complete.

The name of this order is from two Greek words: *lepis*, a scale, and *pteron*, a wing. It refers to the fact that the wings of these insects are covered with scales. Every lad that lives in the country knows that the wings of moths and butterflies are covered with dust, which comes off upon one's fingers when these insects are handled. This dust when examined with a microscope is found to be composed of very minute scales of regular form, and when a wing is looked at in the same way the scales are seen arranged with more or less regularity upon it (Fig. 70). The body, the legs, and other appendages are also covered with scales.

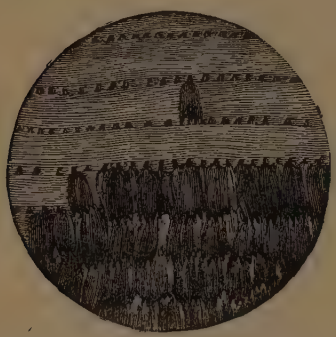


FIG. 70.—Part of a wing of a butterfly, greatly magnified. The scales were removed from a portion of the specimen figured.

This order has been discussed in Lessons XXIII to XXV, and several representatives of it are de-

Plate III.—SOME SPHINX MOTHS.

FIGURE

1. The Abbot Sphinx, *Thyreus abboti*. The larva feeds on grape.
2. The White-lined Sphinx, *Deilephila lineata*. The larva feeds on apples, grapes, and many other plants.
3. The Dark-veined Deilephila, *Deilephila gallii*. The larva feeds on grape.
4. The Bumblebee Hawk-moth, *Hemaris diffinis*. The larva feeds on the bush honeysuckle and the snowberry.
5. The Nessus Sphinx, *Amphion nessus*. The larva feeds on grape and rubiaceæ.

Plate III

scribed in the chapters following this one. The principal divisions of the Lepidoptera that are appropriately discussed here are three: The moths, the skippers, and the butterflies.

The Moths.—These are the insects commonly called millers. Most of the species fly by night and are frequently attracted to lights. When at rest the

FIG. 71.—A moth with threadlike antennæ.

wings are either wrapped around the body, or are spread horizontally, or are folded rooflike on the abdomen; they are not held in a vertical position above the body. The antennæ of moths are of vari-

FIG. 72.—A moth with featherlike antennæ.

ous forms; they are usually threadlike or featherlike; only in rare cases are they enlarged toward the tip (Figs. 71, 72).

The Skippers.—The skippers are so called on ac-

count of their peculiar mode of flight. They fly in the daytime and dart suddenly from place to place. When at rest they usually hold the wings erect in a vertical position like butterflies; often the fore wings are thus held while the hind wings are extended horizontally. The antennæ are threadlike, and enlarged toward the tip; but in most cases the extreme tip is pointed and recurved, forming a hook. The

FIG. 73.—A skipper.

FIG. 74.—A skipper.

abdomen is usually stout, resembling that of a moth rather than that of a butterfly (Figs. 73, 74).

FIG. 75.—The goat-weed butterfly.

The Butterflies.—The butterflies fly by day, and when at rest they fold the wings together above the back in a vertical position. The antennæ are thread-

like with a club at the tip, which is never recurved so as to form a hook. The abdomen is slender (Figs. 75, 76).

FIG. 76.—The banded-purple butterfly.

Order DIPTERA (Dip'te-ra).
The Flies.

The members of this order have only two wings; these are borne by the mesothorax. The metathorax is furnished with a pair of knobbed threads—the halteres. The mouth-parts are formed for sucking. The metamorphosis is complete.

To the order Diptera belong all insects that are properly termed flies, and only these. The word "fly" forms a part of many compound names of insects of other orders, as butterfly, stone-fly, May-fly, and Chalcis-fly; but when used alone, it is correctly applied only to dipterous insects. To some flies other common names have been applied, as mosquito, gnat, and midge.

The name Diptera is from two Greek words: *dis*, two, and *pteron*, a wing. It was suggested by the fact that the flies are distinguished by the possession

of a single pair of wings; for no fly has more than two wings, and only a few are wingless.

The common house-fly is the best-known representative of this order. Fig. 77 represents a crane-fly, so called on account of its long legs. In this figure the halteres, which represent the hind wings in this order, are well shown. Several families of flies are referred to in the following chapter.

FIG. 77.—A crane-fly.

Order SIPHONAPTERA (Siph-o-nap'te-ra).

The Fleas.

The members of this order are practically wingless, the wings being represented only by minute scaly plates. The mouth-parts are formed for sucking. The metamorphosis is complete.

The name of the order is from two Greek words: *siphon*, a tube, and *pteros*, wingless. It refers to the form of the mouth and to the wingless condition of the insects. Fig. 78 represents the dog-flea and its larva.

FIG. 78.—The dog-flea and its larva.

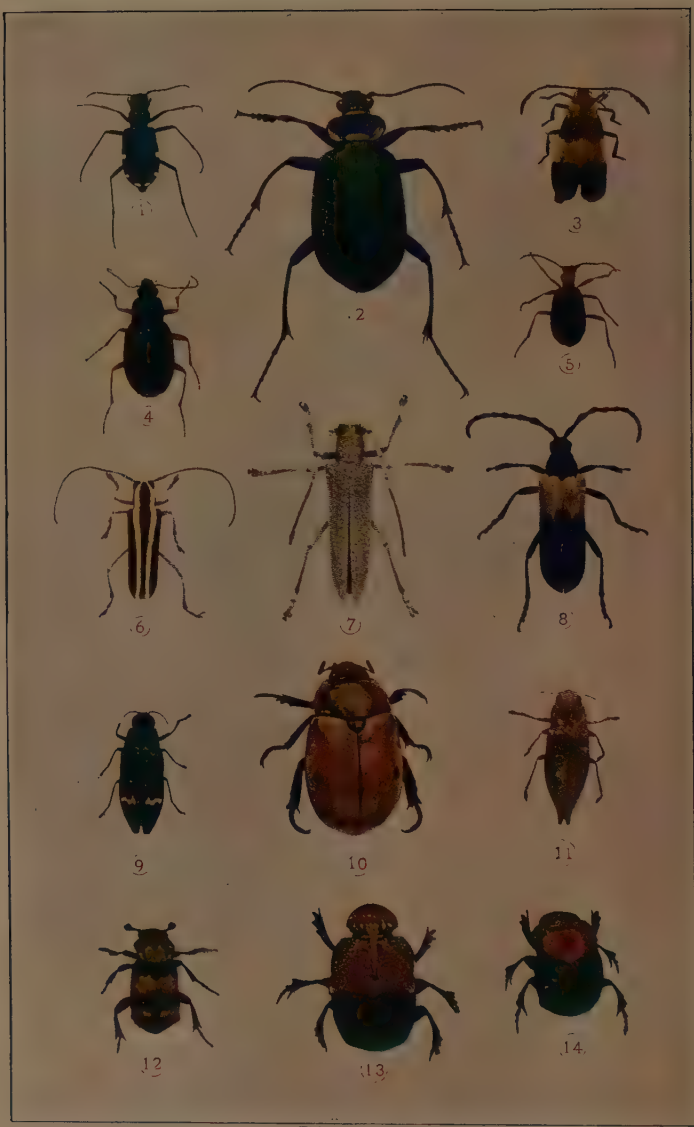


Plate IV

Plate IV.—BEETLES.

FIGURE

1. The Six-spotted Tiger-beetle, *Cicindela sexguttata*. See page 270.
2. The Searcher, *Calosoma scrutator*. A predaceous beetle.
3. *Calopteron reticulatum*, a diurnal member of the firefly family.
4. *Chlænius sericeus*, a ground-beetle.
5. *Brachynus fumans*, a bombardier beetle.
6. The Round-headed Apple-tree Borer, *Saperda candida*.
7. The Poplar Borer, *Saperda calcarata*.
8. The Cloaked Knotty-horn, *Desmocerus palliatus*. The larva bores in the pith of elder.
9. *Buprestis fasciata*, one of the metallic wood-borers.
10. The Spotted Pelidnota, *Pelidnota punctata*. It feeds on the leaves of grape.
11. *Dicerca divaricata*, one of the metallic wood-borers; the larva bores in peach, cherry, beech, and maple.
12. A burying beetle, *Necrophorus*.
13. *Phanæus carnifex*, male; one of the tumble-bugs.
14. *Phanæus carnifex*, female.

Plate IV.—Beetles.

Order Coleoptera (Co-le-op'te-ra).
The Beetles.

The members of this order have a pair of horny wing-covers, called elytra, which meet in a straight line down the back, and beneath which there is a single pair of membranous wings. The mouth-parts are formed for biting. The metamorphosis is complete.

Beetles can be readily distinguished from all other insects except earwigs by the possession of horny, veinless wing-covers, which meet in a straight line down the back (Fig. 79); and they differ from earwigs in lacking the pincer-like appendages at the tail end of the body characteristic of those insects (see page 70). Beetles also differ from earwigs in having a complete metamorphosis.

Fig. 79.—A beetle.

The name of the order Coleoptera is from two Greek words: *coleos*, a sheath, and *pteron*, a wing. It refers to the sheathlike structure of the elytra (el'y-tra) or wing-covers, which were formerly believed to be modified wings.

This order has been studied in Lessons XVIII to XX, and several families are described in the following chapters.

Order Hymenoptera (Hy-me-nop'te-ra).
Bees, Wasps, Ants, and Others.

The members of this order have four wings; these are membranous, and furnished with comparatively few or

with no transverse veins. The hind wings are smaller than the fore wings. The mouth-parts are formed for biting and sucking. The abdomen in the female is usually furnished with a sting, piercer, or saw. The metamorphosis is complete.

The bees, wasps, and ants are among the better-known insects, and will serve to give an idea of the characteristic appearance of the members of this order. They are chiefly insects of small or moderate size, and many of them abound wherever flowers bloom. From the earliest times they have been favorites with students of the habits of animals, for among them we find the most wonderful developments of instinctive powers. Many volumes have been written regarding their ways, and much remains to be discovered, even concerning our most common species.

FIG. 80.—An ichneumon-fly.

The name of the order is from two Greek words: *hymen*, membrane, and *pteron*, a wing. It refers to the fact that the wings are of a delicate membranous tex-

FIG. 81.—An ensign-fly.

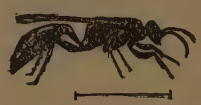


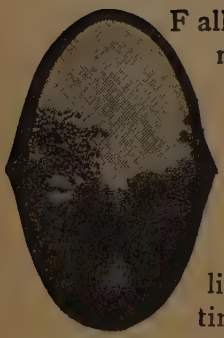
FIG. 82.—A digger-wasp.

ture; but this characteristic is not distinctive, for it is possessed by the wings of many other insects. Figs. 80, 81, and 82 represent members of this order.

PLATE V. A POND.

CHAPTER IV.

POND LIFE.



OF all delightful fields for Nature study none can surpass in interest a well-stocked pond, for there is a peculiar fascination in the study of pond life. Even to one who knows little about Nature, a pretty pond, partly shaded by trees and fringed with water-plants, is a source of delight. What pleasure when one is tired to lie on a grassy bank and watch the ripples chase each other over the water, or to thread one's way through a rank growth of sedges and rushes to where the cat-tail flags rear their tall spikes, and the sweet-scented water-lilies lift themselves above their shield-shaped leaves, or to float in a boat and watch the clouds above and their doubles in the mirror below!

Such experiences bring rest and a feeling of harmony with Nature. But a keener enjoyment comes with a more intimate acquaintance with the forms of life that abound in these places, when one can look upon each kind of water-plant as an old friend, and know something of the ways of the creatures that glide over the surface or swim beneath.

There is a pond that we love to visit when we are tired with work at our desks. It is a long, narrow one that winds beneath overhanging trees, and is margined with a dense growth of water-plants. Over this pond dragon-flies hawk at midges; on a dead tree near the bank a kingfisher has his perch, from which on our approach he swoops down twirling his watchman's rattle; sometimes in the swamp near by we frighten up a bittern; and in the shallows near the shore the great blue heron loves to fish, standing knee-deep in the water watching patiently for his victims.

Here, too, occur large colonies of whirligig-beetles, which chase each other round and round as if at play; water-striders skim over the surface; the marsh-treader glides on its stiltlike legs among the rushes and floating leaves; and, beneath the surface, water-boatmen, back-swimmers, water-scorpions, diving-beetles, and many other strange creatures abound.

We go to this pond and watch these creatures in their homes and then we bring some of them to our study, where we put them in aquaria, and try to learn more about their ways.

Similar ponds can be found in most country places, and the following pages of this chapter are written to aid others in making similar studies.

In the studies of life histories the pupil should be very careful in his observations; it is easy to make mistakes. Do not be satisfied with seeing a thing once, but observe it over and over again. *Make sure you are right and then look again.* This is the only way in which good scientific work can be done, and

every pupil can be a scientific observer if he has eyes and will use them properly.

INSECTS THAT FLY OVER PONDS.

THE DRAGON-FLIES, OR DARNING-NEEDLES, AND THE DAMSEL-FLIES (*Field Work*).—It is a field day, and we find ourselves near our favorite pond, drawn here by a charm we do not care to resist. We are seated on a convenient log on the bank. Below us lies the water without a ripple on its surface, and whether we look up or look down we see the same beautiful foliage of the graceful trees that line the shores. Fringing the bank beyond is a bed of lilies, whose shields float on the surface, and at our feet great arrowlike leaves point upward. Not a breath stirs a branch, and so still is it that it seems as if no living thing were here except the invisible, silent stream of life within twig and leaf. Suddenly there shoots over the pond that swiftest of winged creatures, a dragon-fly. So rapid is its flight that we can hardly follow it with our sight. Back and forth it goes, when, discovering strangers, it darts in front of us and suddenly stops in midair. Here it hangs for a moment motionless, except for its rapidly vibrating wings, and then as suddenly darts away.

What a pity that children should be taught to fear this beautiful, harmless creature by the silly legend that it will sew up their eyes and ears!

The habits of dragon-flies are such that they can be studied only in the field; the roomiest of breeding cages would offer slight scope for the powers of these insects. We must therefore watch them while free if we would learn what they do.

Yonder flies a tiny insect, a midge or a mosquito; as we watch it, a dragon-fly darts at it and it is gone. Now that we have learned what to watch for, we see insect after insect destroyed by the rapacious creature; no wonder that it is called a *dragon*.

Other dragon-flies have come to our pond. Some of them are behaving quite differently from the one that is hawking mosquitoes. They soar over the pond, and at frequent intervals swoop down and touch the water with the tip of the abdomen. Why do they do this? Are they at play splashing the water like a child? No, these are females laying their eggs. The young of dragon-flies lead a very different life from that of the adult. They live beneath the water upon the bottom of the pond or stream as the case may be; and the adult places her eggs in such a position that when the young hatch they will be in their proper element.

Not all dragon-flies lay their eggs as these are doing. On one occasion the writer, in company with his class, saw a dragon-fly poising herself in the air a short distance above the point where a water-plant emerged from the water. At frequent intervals the insect descended with a swift curved movement, pushing the end of her abdomen into the water. On examination a large cluster of eggs was found attached to the plant just below the surface. And Prof. Uhler has observed a dragon-fly alight upon a reed, and, pushing the end of her body below the surface of the water, glue a bunch of eggs to the submerged stem.

The dragon-flies that we have been observing hold their wings spread out stiffly when at rest (Fig.

83). But there are certain insects, abundant about a ditch near this pond, which resemble these dragon-

FIG. 83.

flies very closely in structure, but differ in that they fold their wings parallel with the body when resting (Fig. 84). They have not the great powers of flight possessed by the dragon-flies that do not fold their wings, but flit airily from plant to plant. The more gentle habits of these insects have led the French to call them *demoiselles* or damsels.

FIG. 84.

English writers heretofore have classed both of these kinds of insects under the name dragon-flies, but in the following pages we will restrict the name dragon-flies to those that hold their wings spread out and term those that fold their wings damsel-flies.

There is a great variety of damsel-flies. Some have nearly

colorless wings and comparatively dull-colored bodies, while others have shiny-black wings and brilliant, metallic-green or blue bodies.

The damsel-flies lay their eggs in a remarkable manner. These insects have well-developed ovipositors with which they can make incisions in the stems or leaves of plants; and some of the species at least, when they wish to lay their eggs, crawl down the stems of aquatic plants and lay their eggs in them beneath the water.

Can it be that the habit of folding their wings when they are not in use is correlated with the peculiar egg-laying habits of these insects? Certainly it would be difficult for them to creep beneath the water were their wings expanded like those of dragon-flies.

Let those who have accompanied us on this field trip try to learn something new about dragon-flies and damsel-flies. This they can do by patiently watching. They can learn upon what kinds of insects these creatures feed; they can observe differences in their modes of flight, and in the regions which each prefers to haunt; and they can ascertain more than we now know regarding the various ways in which they lay their eggs. As soon as an observation is made, it should be recorded in a notebook or on slips of paper carried for this purpose.

After observations have been made on one of these insects, that particular one should be captured if possible, so that the record of the observation may be completed by determining the particular species observed.

Other specimens should be taken for study at school and for preservation in your collection.

It is exceedingly difficult to catch dragon-flies while they are on the wing. Watch them till one alights, and then approach it quietly till within reach of it and capture it with a very quick sweep of the net. Damsel-flies, however, are easily captured.

THE HABITS OF DRAGON-FLIES AND DAMSEL-FLIES (*School Work*).—Write an account of an excursion that you have made yourself to a pond or stream, and include in it the observations that you made on dragon-flies and damsel-flies. State also in this account whether you believe these insects to be injurious or beneficial to man, and the reasons for this belief.

Copy the following label and place it above the dragon-flies and damsel-flies in your collection: *

Order ODONATA (Od-o-na'ta).
The Dragon-flies and Damsel-flies.

Blue dragon-flies knitting
To and fro in the sun,
With sidelong jerk flitting
Sink down on the rushes,
And, motionless sitting,
. . . .
With level wings swinging
On green tasseled rushes,
To dream in the sun.—*Lowell.*

THE STRUCTURE OF DRAGON-FLIES (*School Work*).—Select for study one of the large dragon-flies collected on the last field day, one of those that hold the wings spread out when at rest. If you failed to

* In writing these labels, underscore the word in capitals with two lines, and the words in *italics* with a single line. See example, page 42.

get any, borrow one of some more successful collector. Do not touch the specimen itself, lest you break it, but handle it by means of the pin with which it is pinned.

1. Observe the general appearance of the insect, noting the large head, the slender neck, the stout thorax, the broadly expanded wings, and the long, slender abdomen.

2. Study the head, noting its shape, the puffed out front portion, the concave hinder side, and the large compound eyes.

3. Examine the compound eyes with a lens or microscope, and make a drawing illustrating the structure of the surface; only a small portion of one eye need be represented, but show this greatly enlarged. State the proportion of the surface of the head occupied by the compound eyes.

4. Find the simple eyes, using a lens for this purpose; they are situated in the triangular space between the compound eyes and the puffed out front portion of the head. How many of them are there?

5. Observe the antennæ; these are very small, and are situated in the same triangular space as the simple eyes. Each antenna consists of a stouter basal part and a slender, bristlelike part composed of several segments. Make a drawing of one antenna greatly enlarged.

6. Make a drawing of the head seen from above, representing each of the parts already mentioned. Make the drawing large enough so that the simple eyes and antennæ can be well shown.

7. Study the lower side of the head and make a drawing of the mouth-parts that can be seen without

dissection. These are the upper lip or labrum, the tips of the mandibles, and the lower lip or labium. The maxillæ are usually concealed when the mouth is closed. The labium is very large and ends in three broad flaps, one below the mouth and one on each side; the one below the mouth is sometimes more or less split on the middle line, and each of the side flaps bears a slender appendage; sometimes, however, these appendages are very minute.

8. Study the parts of the head already examined with a view to seeing how they are fitted to their use. The most conspicuous parts are the very large eyes; evidently the sense of sight is exceedingly important to these insects; note also that the shape of the eyes is such that the insect can see in all directions without making any movement of the head or body. Regarding the simple eyes, we can only say that three well-developed ones are present; no one has yet discovered the peculiar use of these eyes as distinguished from that of the compound eyes, but it seems as if they must have a function different from that of the compound eyes, else why should an insect with such highly developed compound eyes possess simple eyes also. In many insects the sense of smell is believed to have its seat in the antennæ; if that is so in dragon-flies, it is evident that comparatively little use is made of this sense by these insects, for the antennæ are so slightly developed as to be little more than rudimentary organs; but it is not strange that insects so well provided with organs of sight should have little use for organs of smell in hawking their prey or in seeking their mates. The mouth-parts are admirably fitted for seizing and

holding the small insects upon which the dragon-flies feed. It is also probable that the freedom of movement of the head resulting from the slenderness of the neck is of great use to these insects in seizing their prey.

9. Study the peculiar features of the thorax, noting the following points: Its large size—this is necessary to give room for the large and powerful muscles that move the wings. The position of the legs—these are situated much farther forward than is usual with insects, all of the legs being nearer the head than the wings. The legs are used but little for walking, their chief use being for clinging to some support and, perhaps, for seizing prey. With most insects the middle and hind pairs of legs are attached to the thorax farther back than are the corresponding wings, and consequently the side pieces of the thorax between the wings, and these legs slope *backward* and downward from the wings. This is shown in Fig. 85, which represents a side view of a locust with its wings removed. In a dragon-fly these side pieces of the thorax slope *forward* and downward. Make a drawing of a side view of a dragon-fly, illustrating this point; the wings need not be represented, and only the bases of the legs need be shown, as is done in the figure of a locust.

FIG. 85.

10. Examine the legs of the dragon-fly, noting the spines borne by the femur and tibia. Consider the possible use of these spines in catching and hold-

ing prey. Make a drawing of one of these legs and label the following parts: coxa, trochanter, femur, tibia, tarsus, and claws.

11. Study the wings. These wings are of especial interest, for, judging by the powers of flight of these insects, they must be extremely well fitted for their use. Although large they are very light; yet notwithstanding their lightness they are strong, being strengthened by a large number of veins and veinlets, and the margin of the wing is strengthened throughout by an ambient vein. Near the middle of the length of the frontal (costal) margin of each wing there is a jointlike structure: this is called the *nodus;* this structure is characteristic of the wings of dragon-flies and damsel-flies, but its use is not known. The front part of each wing, which is the part where the greatest strength is required, is folded in plaits somewhat like a fan. This adds greatly to the strength of the wing. Take a flat piece of writing paper and observe how easily it can be bent. Now, fold this piece of paper like a fan and see how much stiffer it is. Study the cross-veins extending back from vein I (i. e., the front margin of the wing) and note that some of them extend straight across the furrow to vein III (the second vein from the margin), and are in the form of triangular braces that tend to preserve the form of the furrow.

12. The abdomen is long, and usually quite slender. The necessity for the great length of the abdomen is not quite clear; it may be that the abdomen serves to steady the flight like the shaft of an arrow; and, too, there may exist a relation between the form of the wings and that of the abdomen. With most

swiftly flying insects, as the bees, wasps, hawk-moths, and others, the hind wings are reduced in size, and thus there is a concentration of the powers of flight to a region near the front end of the body, which adds to its efficiency, for the opposite arrangement would result like an effort to shoot an arrow with the wrong end forward; with dragon-flies the hind wings are as large as or larger than the fore wings, but the great length of the abdomen results in the flight organs as a whole being comparatively near the front end of the body. It should also be observed that the form of the abdomen is well fitted for the peculiar method of laying the eggs. In the males of dragon-flies there is a slit in the lower side of the second abdominal segment, which contains an organ furnished with hooks. Dragon-flies and damsel-flies differ from all other insects in the position of this organ of the males. Determine the sex of each of your specimens and label them male or female as the case may be.

13. Make a sketch of the dragon-fly seen from above.

THE STRUCTURE OF DAMSEL-FLIES (*School Work*).—Compare the structure of a damsel-fly with that of the dragon-fly already studied. Note especially the form of the head with the eyes projecting like the oarlocks of an outrigged skiff, the shape of the wings, the position of the wings when at rest, and the form of the ovipositor of the females. Make a sketch of the head seen from above. Make a sketch showing the outline of each of the wings of one side. Determine the sex of each of your specimens and label them.

THE MAY-FLIES (*Field Work*).—Let us continue our study of the insects that fly over ponds. In many places, at certain periods of the year, the most abundant of these are the May-flies. These are very fragile insects with large, delicate fore wings, with the hind wings much smaller or wanting, and with the abdomen furnished at its caudal end with either two or three many-jointed, threadlike appendages (Fig. 86).

FIG. 86.

Although a few May-flies can be found at almost any time during the warmer parts of the year, in each locality there are certain periods during which they are much more abundant than at other times; then they are apt to appear in great swarms. This period is as likely to be in June or July as in May, despite the common name of these insects. It is at such times that a study should be made of their habits. If you find that May-flies are abundant at any time and you have not already made a study of them, it will be worth while to postpone the study of any other insects and devote your attention to these, for no other insects described in these lessons have so short a period of flight as the May-flies. While in the field take notes on the following points:—

1. The flight of these insects—contrast it with that of dragon-flies.

2. The food of May-flies—can you find any that are catching other insects or that are feeding on plants?

3. The young of May-flies live in the water. Try to observe the emergence of the insects from the water.

4. If you succeed in observing the emergence of the winged insect from the water, collect the empty nymph skin and, if possible, the winged individual that emerged from it. These should be preserved together in your collection; they will serve to connect the adult with its early stages.

5. May-flies differ from all other insects in that they shed the skin once after they are able to fly. The winged May-fly when it emerges from the water is not a fully developed adult, but is what is termed a *subimago*. The subimago state is of short duration; sometimes it lasts only a few minutes, but in other species it lasts twenty-four hours or more.

Watch the May-flies that are resting on plants or other objects near the shore and try to observe the molting of the subimago. If you succeed, collect the adult or *imago* and the empty subimago skin, and preserve them together in your collection. Even if you fail to observe the molting, you ought to be able to collect subimago skins if the May-flies are at all abundant.

6. Endeavor to observe the laying of the eggs. Some May-flies lay their eggs in masses; specimens are often found in which there project from the caudal end of the body two parallel, subcylindrical masses of eggs, for in these insects the two oviducts open separately.

7. In the evening, examine the street lamps or other lights, and note the extent to which the May-flies are attracted to them.

THE HABITS OF MAY-FLIES (*School Work*).—Write an account of what you have learned regarding May-flies. Copy the following label and place it above the May-flies in your collection (see footnote, page 93):—

Order EPHEMERIDA (Eph-e-mer'i-da).

The May-flies.

THE STRUCTURE OF MAY-FLIES (*School Work*).—It is quite difficult to preserve specimens of May-flies in good condition for study, as they shrivel greatly on drying. We will call attention, therefore, to only a few of the more important points in the structure of these insects.

1. Study the head and observe the following: The very large compound eyes—in dried specimens these are apt to be more or less shriveled, and in some kinds of May-flies each compound eye is divided into two distinct parts; the simple eyes or ocelli—in some of our more common species these are much larger than is usual with insects; the mouth-parts—these are absent or represented by minute rudiments. May-flies take no food during their very short existence in the adult state. Make a sketch of the head seen from above.

2. Study the wings and make a sketch showing the outline of each of the two wings of one side.

3. Write out a statement of the points of resemblance and the points of difference between the wings of May-flies and those of dragon-flies.

4. Make a sketch of a May-fly seen from above.

THE STONE-FLIES (*Field Work*).—Among the insects that are common flying about ponds and streams are the stone-flies. Fig. 87 represents one of our larger species with the wings of one side spread out. When at rest these insects fold their wings upon the back, as shown on the left side of the figure. Most of our species are much smaller than the one represented here, but they can be recognized as stone-flies by their resemblance in form to this one. The body is flattened, elongate, and with the sides nearly parallel; the prothorax is large; the antennæ are long, tapering, and many jointed; in most species the caudal end of the abdomen is furnished with two slender appendages. Stone-flies are so called because they pass their early stages beneath stones in streams and ponds.

FIG. 87.

1. Collect as many kinds of stone-flies as you can, saving several specimens of each kind.

2. Make notes on their powers of flight.

3. Make notes on the localities in which they occur.

4. Try to discover the method in which they lay their eggs.

THE STRUCTURE AND HABITS OF STONE-FLIES (*School Work*).—Write an account of what you have learned regarding stone-flies. Describe first the appearance of these insects; illustrate this by two sketches, one showing the appearance of the insect as seen from above with the wings closed, the other an enlarged view of the head and prothorax as seen from above, and compare the eyes and antennæ with those of dragon-flies and May-flies. In the second part of the account state what you have learned regarding the habitat and habits of stone-flies.

Copy the following label and place it above the stone-flies in your collection (see footnote, page 3):

Order PLECOPTERA (Ple-cop'te-ra).
The Stone flies.

OTHER INSECTS THAT FLY OVER PONDS (*Field Work*).—During the field days, when you are studying pond life collect any insects that you find flying over ponds or resting near them. These should be carefully pinned, labeled, and preserved in your collection for future study.

INSECTS THAT LIVE ON THE SURFACE OF WATER.

In the excursions that have been made for the purpose of studying pond life, the pupils have probably observed certain insects running over the surface of the water as if it were a firm pavement. We purpose to study carefully some of these insects, but before doing so it will be well to endeavor to understand how it is that these creatures can perform the apparent miracle of walking upon water.

THE SURFACE-FILM OF WATER (*School Work*).—One of the astonishing facts to be learned by the study of pond life is that many insects are able to walk upon water, and equally strange is the fact that certain other insects that live within water can hang from its upper surface without any effort to keep themselves there, although their bodies are heavier than water.

These things seem to contradict the well-known law of Nature that an object can not float in a liquid unless it is lighter than that liquid. And in truth it is a fact that under certain conditions objects that are much heavier than the liquid upon which they are placed will float.

This phenomenon is due to the presence of what has been termed the surface-film of liquids. It has been shown by many experiments, some of which are given below, that on the surface of water, and other liquids also, there is a film of the liquid which tends to contract as if it were a membrane stretched equally in all directions. The explanation of the formation of this film is a difficult matter, which can not be undertaken here. It is discussed in the more advanced works on physics and in some of the larger cyclopædias under the head of capillary attraction. The action of the surface-film can be seen by the following experiments:

Experiment 1.—Take a fine needle and carefully lay it on the surface of a glass of water. To do this hold the needle in a horizontal position and bring it as near the water as you can without touching the water and then drop the needle. If the experiment be performed with sufficient care, the needle will

float. Steel is seven times heavier than water; nevertheless, in this experiment we see a piece of steel floating on the surface of water.

Experiment 2.—Take a needle that you have caused to float on the water and wet it thoroughly. Now you will be unable to make it float so long as it is wet. This experiment indicates that one of the conditions of floating of a heavy object is that it shall not be wet by the liquid.

Experiment 3.—Take needles of different sizes or short pieces of different sizes of wire, and, having them perfectly dry, try to make them float. In this experiment it is well to lay the piece of wire across the tines of a fork and lower it gently into the water. It will be found that only the smaller needles or pieces of wire will float. This experiment indicates that a second condition of the floating of a heavy object is that it shall be comparatively small.

Experiment 4.—Take a glass of water and place it on a stand so that you can look through the side of the glass at the surface of the water both from above and below. Place a needle upon the water, the larger the needle the better, provided it will float. By studying the floating object carefully it will be seen that it rests in a little hollow with sloping sides, the surface of the water being indented as if it were covered with a membrane stretched across it.

There are many other interesting phenomena that are explained by a knowledge of the action of the surface-film of liquids, but their study belongs to the subject of physics; only so much has been introduced here as is necessary to understand what we will see in our study of pond life.

THE WATER-STRIDERS (*Field Work*).—Now that we have studied the surface-film of water, let us visit some pond or stream and observe those insects that live upon it. Chief among these are the water-striders, the long-legged creatures that skate over the surface as if they had no weight.

There are a good many species of water-striders, and several quite distinct types, differing in size, in the form of the body, and in the relative length of the legs. One of the more common forms is represented by Fig. 88. Try to find some of these, for owing to their larger size it will be easier to observe them than other kinds; but if you are unable to find these, study any water-striders that you can find and make notes for an account of them.

FIG. 88.—A water-strider.

1. Water-striders live upon both ponds and streams; if you are observing them upon a stream, note what portions of the stream they prefer.

2. Do they occur singly or in colonies?

3. Are they shy or otherwise?

4. Are they disturbed by fish? To determine this watch them where there are fish, and throw grasshoppers or other insects into the water and note if the fish are more apt to jump at these than at the water-striders.

5. Throw some insect into the water where there are no fish, but near some water-striders, and note the actions of the latter. What is likely to happen

to an insect that falls into the water where there are water-striders?

6. Watch the water-striders and learn if they will jump from the water to catch insects that fly near it.

7. Remain quiet at the shore of the pond or stream till the water-striders approach near enough to be observed closely and determine what portions of the body rest upon the water.

8. Observe the dimples in the water where the feet rest on the surface.

9. When the sun is shining brightly, find some water-striders where the water is shallow and observe on the bottom of the pool the shadows of the dimples in the water made by the feet of the insects. Note that each shadow is surrounded by a golden ring of light. The more advanced pupils should be able to explain the cause of this ring of light. Note that there is no ring of light about the shadow cast by the body; why is this so?

10. Make a sketch showing the outline of the body and the position of each of the legs and the antennæ when the insect is at rest.

11. Discover which pair of legs are the chief organs of locomotion in the striding of these insects.

12. Collect as many kinds of water-striders as possible, saving several specimens of each species. Kill them in your cyanide bottle and then pin them on your return home.

Water-striders are dimorphic—that is, there are two distinct forms of fully developed individuals in each species. One form is winged, the other wingless. Try to procure both the winged and the wingless form of each species collected. The presence

of winged forms probably enables these insects to spread overland from one pond or stream to another, but the conditions under which winged forms occur are not well understood. Sometimes a third form occurs in which the adult has short wings. It should be remembered that the nymphs of the winged forms have short wing-pads, but these differ in appearance from perfect wings.

THE FAMILIES OF WATER-STRIDERS (*School Work*). —There are two closely related families of bugs the members of either of which could well be called water-striders on account of their mode of life. In one family the legs are much longer than in the other, and better fitted for the gliding motion characteristic of water-striders; the members of this family are termed "the water-striders." In the other family the legs are shorter and fitted for running rather than rowing; as the body is broadest across the prothorax in these insects, they are termed "the broad-shouldered water-striders."

Separate from the others those specimens of water-striders in your collection in which the second and third pairs of legs are extremely long and slender, and in which the body is widest back of the prothorax. If this family is well represented in your locality, you should have some species in which the body is long and slender, as in Fig. 88, and also some smaller species in which the body is oval in outline.

Copy the following label and fasten it above the place where the water-striders are to be put in your collection:—

Order HEMIPTERA (He-mip'te-ra).
The Bugs.

Place immediately below this label the following one, and then arrange the water-striders just selected beneath this second label; put each species of water-strider in a row by itself:—

Family HYDROBATIDÆ (Hyd-ro-bat'i-dæ).

The Water-striders.

Fig. 89 represents a member of the second family of water-striders, somewhat enlarged. These insects can be distinguished from the true water-striders by their comparatively short legs and broad prothorax. If you have any specimens of this family arrange them just after the true water-striders and below the following label:—

FIG. 89. — A broad-shouldered water-strider.

Family VELIIDÆ (Ve-li'i-dæ).

The Broad-shouldered Water-striders.

THE HABITS OF WATER-STRIDERS (*School Work*). —Write an account of what you have learned regarding water-striders.

THE STRUCTURE OF WATER-STRIDERS (*School Work*).—Select one of the true water-striders, preferably a large one like that represented by Fig 88, and study the following parts.

1. The body is covered with microscopic hairs, those on the lower side are longer and usually silvery white in color. These doubtless form a waterproof coating, and add much to the beauty of the insects, causing them to appear like white-bottomed boats when on the water.

2. The head is inserted in the prothorax up to the base of the eyes. The eyes, though small compared with those of the dragon-fly, are really quite large and prominent; their shape and position are such that the insect can readily see in all directions. The antennæ are long and consist of four segments. The beak arises from the forward end of the head; when not in use it usually extends backward between the fore legs. It consists of four segments; the second segment, however, is quite short and liable to be overlooked. A bristlelike piercing organ can usually be seen protruding from the tip of the beak. Make a drawing of a side view of the head, showing the form of the head, eyes, antennæ, and beak.

3. Study the position and form of the legs. The fore legs are placed well forward, and are stouter than the others; they are used for seizing and holding the prey. The middle and hind legs are placed far back, and are the chief organs of locomotion, the middle legs being used as oars and the hind legs as rudders. A striking peculiarity of the legs in the two families of water-striders is that the last segment of the tarsus is split at the end and the claws are inserted in this cleft; this is most easily seen in the stouter fore legs than in the threadlike middle and hind legs of the true water-striders. In the broad-shouldered water-striders it is easily seen on any of the legs. Make a drawing of the tarsus of one of the legs, showing this peculiarity.

4. Make a drawing of the lower side of the abdomen, noting carefully the form of the segments near the caudal end.

5. Study all the specimens you have of water-striders and see if you can separate the sexes.

THE WHIRLIGIG-BEETLES (*Field Work*).—No lad who has loitered much by ponds or wandered along the margins of brooks with open eyes can have failed to see the whirligig-beetles, those social fellows that gather in large numbers and chase each other round and round in graceful curves with wonderful rapidity. These beetles are oval or elliptical in form, more or less flattened, and usually of a very brilliant, bluish-black color above, with a metallic luster; one of our common forms is represented by Fig. 90, but some of the smaller species are proportionally longer and more convex.

FIG. 90.

Seek for specimens of whirligig-beetles on the surface of the ponds and streams in your locality and, when found, watch them carefully, note-book in hand, and record all that you can see of their ways.

Take with you on this field trip some empty bottles, in which to bring home living specimens, and an insect net; you will need the latter in catching these wary creatures.

Note the peculiar odor emitted by the insects when caught; this is caused by the milky fluid which the insects emit from various joints of the body, and is probably a means of defense.

As these insects can be easily kept alive in aquaria, we will make a more careful study of their habits in confinement.

Comparatively few whirligig-beetles can be found in the spring; these are individuals that have sur-

vived the winter. A new generation begins to appear early in the summer, and they are most abundant late in August or early in September. As cold weather comes on they disappear, burying themselves in mud at the roots of water plants for their winter sleep. But they can be kept active in aquaria in warm rooms long after all have disappeared from the surface of ponds and streams.

On your return from the field trip prepare an aquarium with sand or gravel in the bottom and a few water plants anchored in this soil. Put the living whirligig-beetles into this aquarium, and cover it so that the insects can not escape.

Put in a killing bottle some specimens to be used for a study of the structure of these insects.

THE STRUCTURE OF WHIRLIGIG-BEETLES (*School Work*).—1. Pin the specimens in your killing bottle, so that they may be easily handled without injury to them, putting the pin through the right wing-cover a short distance from its base.

2. Study the appearance of one of these insects when seen from above. Note that the hinder part of the body is covered by a pair of horny wing-covers or elytra, which meet in a straight line along the middle of the back. This type of wing-covers is the mark by which beetles are most easily recognized.

3. Study the head as seen from above and make a drawing of this view, showing the following parts: The upper lip—a horny flap projecting from the extreme front end of the head; the clypeus—a narrow piece extending crosswise between the upper lip and

the chief part of the head; the antennæ—these are unusually short and thick (Fig. 91 represents one of the antennæ of a whirligig-beetle greatly enlarged); the compound eyes—these are quite prominent, and are situated a considerable distance from the margin of the head.

FIG. 91.

4. Study the head as seen from below. Here a very remarkable thing will be seen—namely, a pair of large compound eyes in addition to the pair already observed on the upper side of the head. It should be said, however, that these insects really have only two compound eyes, like other insects; but each eye is divided within the head, one part extending to the upper surface of the head and the other to the lower surface. What peculiarity in the mode of life of the whirligig-beetles renders this arrangement of eyes desirable?

5. Study the mouth-parts and observe that instead of a beak for sucking, as with the water-striders, these insects have jaws fitted for biting.

6. Make a drawing of one of the front legs, and label the following parts: coxa, trochanter, femur, tibia, tarsus, claws.

7. The sexes of whirligig-beetles can be distinguished by the fact that in the males the segments of the tarsus of the fore legs are flattened and furnished with a spongy cushion of hairs beneath, while in the females the segments are more nearly cylindrical and do not bear cushions. Separate the sexes of these insects in your collection.

8. Study the middle and hind legs and observe their strangely modified form. While the fore legs are oarlike in form, these are modified into short and

very broad paddles. Fig. 92 represents the form of one of these.

9. Remove with a pin one of the wing-covers and observe the large membranous wing compactly folded beneath it. Although these insects are commonly seen only on water, they have good powers of flight, and migrate from pond to pond by means of their wings. I have taken them at electric lights far from any water.

FIG. 92.

10. The various kinds of beetles taken together constitute the order Coleoptera, and the whirligig-beetles form the family Gyrinidæ of this order. Write the two following labels and place them above the whirligig-beetles in your collection:—

Order COLEOPTERA (Co-le-op'te-ra).
The Beetles.

Family GYRINIDÆ (Gy-rin'i-dæ).
The Whirligig-beetles.

THE HABITS OF WHIRLIGIG-BEETLES (*School Work*).—Watch the living specimens that you have in an aquarium and learn all you can of their habits. The following are some of the points to be observed: Compare their attitude when at rest with that of a water-strider. Describe their method of locomotion. Describe their actions when frightened. Can you see any indications of their method of breathing when under water? How do they remain beneath the water? How do they rise to the surface? In what way do the beetles endeavor to escape from the water? Try to discover what they will eat—

there is some difference of opinion among scientific writers on this point.

After observing these insects at intervals for several days write an account of what you have learned regarding them.

INSECTS THAT REST AT THE SURFACE BUT SWIM BENEATH.

In our studies of pond life up to this time we have observed some of the insects that fly over ponds and some that live upon the surface of water, but a far greater number of insects live within the water. Some of these are fitted for a purely aquatic life, but many find it necessary to come to the surface from time to time to get a supply of air. This latter class of insects, as a rule, rest at the surface in such a position that they have access to the air above the water, and only swim beneath when alarmed or when in search of food. It is this class of insects, those that rest at the surface but swim beneath, that we are to study now.

A COLLECTING TRIP.—Provide yourselves with insect nets and a supply of empty bottles for bringing back living insects. Go to some pond or stream, and, resting quietly on the shore, try to observe some of the insects that live within the water but rest at the surface. If there is no convenient pond and you go to a stream for this purpose, choose the more quiet portions of the stream, and preferably the deeper pools and those in which plants are growing. Approach the water very quietly so as not to frighten the insects. Often when nothing is to be seen at first the observer will be rewarded by a sight of the desired objects if he will sit very still for a time.

After learning what you can by watching, sweep the vegetation beneath the surface of the water with your net, and in this way collect as many kinds of insects as possible. Put the insects into clean bottles so that they may be kept alive.

On your return prepare several aquaria with sand or gravel on the bottom and aquatic plants anchored in the sand; if practicable prepare as many aquaria as you have kinds of insects, so that one kind shall not destroy another. But in order to observe predaceous insects capture their prey it is necessary to put other insects with them when you are ready to make the observation. After the insects have been placed in the aquaria you will soon be able to learn which ones belong to the class that rest at the surface but swim beneath.

THE PREDACEOUS DIVING-BEETLES (*School Work*). —If a collecting trip like that outlined above is a successful one, there are almost sure to be several kinds of beetles among the insects collected. These can be recognized by the horny wing-covers, which meet in a straight line along the middle of the back. If we omit certain small beetles which are not likely to be studied by the beginner, the beetles collected in this way will represent only two families; one of these families is the Dytiscidæ, or predaceous diving-beetles. The members of this family can be recognized by the fact that when at rest they hang head downward with the tip of the abdomen at the surface of the water. Figs. 93 and 94 represent two of the larger members of this family. There are, however, many small species, measuring less than one fourth of an inch in length, which can be found in

almost any pond. If you can obtain specimens of the larger ones, they will be best for the purposes of study.

Some specimens should be kept alive in aquaria for a study of their habits, and some should be killed and pinned for a study of their structure.

FIG. 93.

FIG. 94.

Place the pinned specimens when not in use in your collection under a copy of the following label and immediately after the whirligig-beetles :—*

Family DYTISCIDÆ (Dy-tis'ci-dæ).
The Predaceous Diving-beetles.

Whenever convenient to do so, watch the diving-beetles and learn all you can regarding their habits. Make a memorandum of whatever you learn; the hints given on page 114 for the study of the whirligig-beetles will be useful here. As these diving-beetles are predaceous, they may be fed with other insects or bits of raw meat. If properly cared for, they can be kept alive in aquaria for a long time, even several years.

THE STRUCTURE OF THE PREDACEOUS DIVING-BEETLES (*School Work*).—Select for study specimens of the largest species of predaceous diving-beetles in your collection and observe the form of the following parts :—

* No effort is made in these outlines to indicate a natural sequence of the families studied. It will be sufficient for the purposes of beginners to place each family under the order to which it belongs, placing first those studied first.

1. The body as a whole. Observe its evenly rounded outlines, and consider how well fitted it is for gliding through the water.

2. The antennæ. These are inserted immediately in front of the eyes, and are threadlike in form, each consisting of twelve similar segments (Fig. 95). The form of the antennæ is an important characteristic of these insects, for by it they can be distinguished from the water-scavenger beetles, which they closely resemble in general appearance.

FIG. 95.

3. The hind legs. These are fitted especially for swimming, being long and more or less oarlike; the tarsus is flattened and fringed with hairs, and the segments of it taper evenly from its base to the claws. Make a drawing of one of these legs.

4. The middle legs. These do not differ greatly from the usual form of the legs of insects, except that in the males of certain species the first three segments of the tarsus are much wider than the others and furnished with cushions beneath.

5. The fore legs. In the females these legs are also of the usual form. But in the males of our common larger species the first three segments of the tarsus are dilated and form a circular disk, upon the under side of which are little cuplike suckers. These suckers differ in size and arrangement in different genera; Fig. 96 represents a tarsus of *Dytiscus* (*Dytis'cus*).

6. Examine the fore legs of all of your pinned specimens of the larger diving-beetles and separate the sexes of each species.

7. If your collection is sufficiently full, you will

be able to observe that in some species there are two kinds of females, one having smooth wing-covers, and another in which the wing-covers are furnished with a number of deep furrows (Fig. 94).

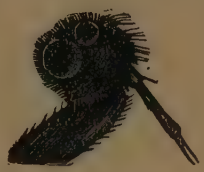


FIG. 96.

8. Study the eyes and compare them with those of the whirligig-beetles.

9. Remove one wing-cover and observe the large wing folded beneath it. These beetles can fly well, and thus migrate from pond to pond.

10. Remove the wing and observe the spiracles or breathing holes on the back near the side of the body.

11. How do these insects breathe when under water?

THE HABITS AND STRUCTURE OF THE PREDACEOUS DIVING-BEETLES (*School Work*).—Write an account of what you have learned regarding these insects.

THE WATER-TIGERS (*Field and School Work*).—These rapacious creatures are the larvæ of the predaceous diving-beetles, and are found in the ponds frequented by these beetles. In sweeping submerged plants for the pond insects already described one is quite apt to obtain water-tigers also. They are elongated, spindle-form grubs, with large sickle-shaped mandibles. Fig. 97 represents one of our larger species. Put the specimens that you collect into an aquarium in which plants are growing, so that the larvæ can crawl to and from the surface easily.

Learn what you can regarding the habits and structure of these larvæ. Observe their favorite

FIG. 97.—A water-tiger.

attitude when at rest. Learn how they obtain air. Place other aquatic insects with them, and observe their predaceous habits and their method of sucking the blood of their victims. Note their methods of locomotion.

In studying their structure, observe the peculiar form of their mandibles; these are large, sickle-shaped, and hollow, with a slitlike opening near the tip. They are admirably fitted for holding the prey and at the same time sucking the blood from its body, as the hollow of the mandibles communicates with the mouth. Observe the spiracles along the sides of the abdomen; these are used but little if at all during the larval stage. The last pair of spiracles are just beneath the tip of the last abdominal segment; it is through these that the larva obtains its supply of air.

Preserve one or more specimens in alcohol and put them with the predaceous diving-beetles in your collection.

THE WATER-SCAVENGER BEETLES (*School Work*).—The water-scavenger beetles are common in quiet pools, where they may be found swimming through the water or crawling among the plants growing on the bottom. If the collecting trip outlined on page

115, was a successful one, there are probably specimens of these beetles in your aquaria; but if you do not already have specimens, go into the field again and sweep plants growing beneath water with an insect net until you get specimens.

FIG. 98.—A water-scavenger beetle.

Fig. 98 represents the largest of our water-scavenger beetles; but we have in this country many smaller species, and the majority of them measure less than one half inch in length.

The members of this family differ in habits from other common aquatic beetles by the fact that when they rest at the surface of the water they keep the head end of the body uppermost. The most easily observed difference in structure is in the form of the antennæ. These are club-shaped (Fig. 99); they are inserted immediately in front of the eyes, and are usually concealed beneath the eyes and prothorax. Care must be taken not to mistake the very long maxillary palpi for the antennæ; these palpi arise from the side of the mouth, and are only three- or four-jointed.

FIG. 99.

Select one of the larger species of water-scavenger beetles and make a study of living specimens in an aquarium, and of the structure of pinned specimens.

Study especially the method in which they obtain air, and the manner in which they carry it when beneath the water.

Observe their food habits. These beetles are supposed to live chiefly upon decaying vegetation in the water, but some of them have been known to feed upon other insects and upon snails.

Arrange your pinned specimens under a copy of the following label and immediately after the Dytiscidæ:—

Family HYDROPHILIDÆ (Hyd-ro-phil'i-dæ).
The Water-scavenger Beetles.

The members of this family form cases in which the eggs are laid. Fig. 100 represents one of these cases attached to a leaf. If you find similar cases preserve them in your collection with the beetles of this family, or place them in an aquarium and try to rear the young.

FIG. 100.

THE LARVÆ OF WATER-SCAVENGER BEETLES (*Field and School Work*).—The larvæ of the water-scavenger beetles live beneath the surface in ponds inhabited by the adults, and may be captured by a sweeping net in the same way as the adults. As they thrive well in aquaria, their habits can be easily observed. They bear some resemblance to water-tigers (Fig. 97), but they can be distinguished from them by the following characters: the body is more plump; the mandibles are not so slender, are not tubular, and are usually furnished with one or more teeth; and the abdomen, in all the species that I have studied, is furnished with backward-projecting spines or with filaments, or with both.

Study the habits of these larvæ. Observe the

method of respiration, the ways of locomotion, and the nature of their food. Offer them both living and dead insects, snails, and meat. Preserve one or more larvæ in alcohol, and put them with the adults in your collection.

THE BACK-SWIMMERS (*School Work*).—When the different kinds of insects that you have collected by sweeping submerged plants have been placed in aquaria, you will be able to recognize the back-swimmers by the fact that they swim upside down. One of these insects is represented back uppermost by Fig. 101.

FIG. 101.

The back-swimmers love to float at the surface of the water. Here they hang motionless, back downward in a slanting position, with the tip of the abdomen at the surface, and the head considerably submerged. When in this position the fore and middle legs are slightly bent, so that the claws are at the surface, as if the insect were clinging to the ceiling of its room; while the longer, oar-like hind legs are nearly straight, and project down into the water somewhat; here they are held in the position of the beginning of a stroke, as if the creature were waiting for the word *go*; and they can go quickly and rapidly like an expert sculler. Often they will swim to the bottom of the pond, where, clinging to a stone or plant, they will rest quietly, apparently as much at home as when at the surface.

In their journeys from one part of the aquarium to another, they are forced to keep their oars in constant motion. For these topsy-turvy creatures carry a load which is so light that the moment they stop

rowing they fall upward. This load is a film of air, which can be seen shining through their wings like burnished silver. Knowing this, we can understand how the back-swimmers can remain so long at the bottom of the aquarium without strangling. Occasionally these insects will float on the surface of the water with the back uppermost; when in this position they can leap into the air from the water and take flight. It is necessary, therefore, to keep aquaria containing them covered, in order to prevent their escape.

Let us study these creatures more closely:

1. Kill two or three specimens by putting them into a cyanide bottle. In handling back-swimmers care must be taken or they will inflict painful stings with their sharp and powerful beaks.

2. When those in the killing bottle are dead, pin them so that they can be handled conveniently. Put the pin through the three-cornered piece on the middle of the back (the scutellum), so as not to fasten the wings down.

3. Hold the insect back downward and note the boat-shaped form of the body, the middle of the back representing the keel.

4. Study the head and observe the following parts: The eyes—these are very large, and each has two large scallops in the outer (lateral) side. The antennæ—these are often so concealed that it is difficult to see them; each is situated just behind that scallop of the eye of the same side which is nearest the mouth. The beak—this projects backward between the legs. What insects already studied have similar mouth-parts? To what order do they belong?

5. Study the legs and observe that the fore and middle legs are furnished with claws, and are fitted for clinging to plants and stones and for seizing prey, while the hind legs are destitute of claws and are fitted for swimming. Make a drawing of one of the hind legs, also one of a fore or middle leg.

6. Study the wings. These are closely folded over the back of the abdomen. The fore wings are thick and heavy at the base, while the tips are thinner and overlap. This type of wing is found only in the order Hemiptera or bugs. Carefully spread the fore wings apart with a pin and observe the hind wings, which are beneath them; these are very thin and transparent; they are stiffened by a few stout veins, and are folded lengthwise on the back of the abdomen; in a recently killed specimen they can be spread with a pin. Like most other pond insects that we have studied, the back-swimmers can leave the water and fly to some other pond if they do not like their surroundings. They do not have this freedom, however, until they are grown up. Early in the summer back-swimmers are found that have no wings; these are the young ones, the nymphs, on which the wings have not yet grown. If you have wingless specimens in your collection, label them *Nymphs.*

7. Study the belly side of the abdomen. Along the middle line there is a prominent ridge which is thickly clothed with hairs, and, on each side between this ridge and the edge of the body there is a deep furrow. Along the upper edge of the outside of this furrow, and a short distance from the side of the body, there is a fringe of long hairs. Wet a pin and

with it carefully brush these hairs toward the side of the body so as to uncover the furrow. When this is done there can be seen on the sloping outer side of the furrow a small hole in each of the segments of the abdomen; these are the spiracles or breathing holes. Note that the ridge on the middle of the belly ends behind in a sharp, projecting point; and that on each side the edge of the body bearing the fringe of hairs also ends behind in a similar point, between which and the tip of the abdomen there is quite a space. This space serves as an opening to an air-chamber between the wings and the abdomen.

8. Take from the aquarium two or three living specimens and put them into a tumbler which is nearly filled with water. Be careful not to be stung while doing this.

9. While a specimen is resting quietly at the surface of the water, study it with a lens. Make a drawing showing the arrangement of the hairs on the abdomen of the living specimen while in the water; this arrangement is very different from that seen on the pinned specimens already studied.

10. Observe, on the living specimen in the water, the hole near the tip of the body through which the air passes into the chambers beneath the fringes of hairs and into the air-chamber between the wings and the abdomen.

11. Study the pinned specimens again, and make sure that you understand how the air can pass to the chambers referred to in the preceding paragraph.

12. On the pinned specimens study the first abdominal segment on the belly side, and observe the

little furrow on each side; these are air-passages extending between the chambers on the belly side of the abdomen to that beneath the wings. (In addition to the spiracles in the abdomen there are spiracles in the thorax; but as these are exceedingly difficult to find, they will not be described here.)

13. Observe living specimens in water and note that they carry air among the hairs on the lower side of the thorax, and in the spaces between the head and prothorax and between the prothorax and the mesothorax. In fact, a large part of the body is enveloped with air. But the most capacious air-chambers are those inclosed by the fringes of hairs on the belly side of the abdomen. It is to the buoyant action of the air in these that the insect owes its peculiar position in the water.

14. If you will watch with a lens living specimens in a glass of water you will be able to see them force the air out of the chambers beneath the fringes of hair, using their hind legs for this purpose, and sometimes an entire fringe will be lifted like a lid.

15. Watch living specimens as they rise to the surface from the depths of the aquarium, and see how they bump against the surface film.

16. Throw living flies into the water where the back-swimmers are and see what the back-swimmers will do. If flies are abundant in the room, observe the fate of those that come to drink from the water.

17. Kill and pin several specimens of each species of back-swimmers that you have collected, and arrange them in your collection under a copy of the

following label, and immediately after the water-striders, for these insects also belong to the order Hemiptera:—

Family NOTONECTIDÆ (No-to-nec'ti-dæ).
The Back-swimmers.

AN ESSAY ON BACK-SWIMMERS (*School Work*).—Write an account of what you have learned regarding back-swimmers.

THE WATER-SCORPIONS (*Field and School Work*).—Among the strange insects that live in ponds, but come to the surface to obtain air, are the water-scorpions. These are not so common as the back-swimmers, but as they are found in similar situations, there may be specimens among those insects in your aquaria collected by sweeping the stems of submerged plants. If not, search for them in the places where back-swimmers are found.

FIG. 102.

FIG. 103.

There are two quite different kinds of water-scorpions in this country. In one of these, called *Nepa* (*Ne'pa*), the body is flat and broad (Fig. 102); in the other, called *Ranatra* (*Ran'a-tra*), the body is long and very slender (Fig. 103). In both, the hind end

of the body is furnished with a pair of long, slender, horny appendages. Each of these is grooved on the inner side, so that when they are held together they form a tube through which air can be drawn. They are represented in this position in the figure of *Nepa* and separate in that of *Ranatra*.

Another interesting feature in the structure of water-scorpions is the form of the fore legs. These are fitted for grasping, and are of such form that each is a complete organ by itself. The coxa is long (in the case of *Ranatra* it is very long, so that it appears like a femur), and the femur is furnished with a groove into which the tibia and tarsus fit like the blade of a pocket-knife into the handle.

The resemblance in form to a scorpion is quite striking in the case of *Nepa* (Fig. 102), but it is much less so with *Ranatra*.

If you succeed in obtaining water-scorpions, keep them in an aquarium and observe their habits. Study their method of obtaining air, the way in which they seize their prey, their modes of locomotion, and any other features of their life history that you can observe.

The body of *Nepa* is very flat, enabling the insect to hide beneath stones and rubbish on the bottom of ponds. With *Ranatra* the slender form of the body and the dirt with which it is usually covered causes the insect to resemble a dirty stick. This resemblance doubtless aids the insect greatly in the capture of its prey.

Adult water-scorpions have well-developed wings which reach nearly to the end of the abdomen; if you find wingless individuals, or some with short wing-pads, label them as nymphs.

The water-scorpions belong to the order Hemiptera. Place your pinned specimens under a copy of the following label and immediately after the back-swimmers:—

Family NEPIDÆ (Nep'i-dæ).
The Water-scorpions.

THE GIANT WATER-BUGS (*Field and School Work*).—These are common insects in quiet ponds. Fig. 104 represents one of the larger species, and Fig 105 a smaller one. All of them can fly well in the adult state, and some are frequently attracted to lights in great numbers. These are known in some parts of the country as "electric-light bugs."

FIG. 104.—Giant water-bug, *Belostoma.*

FIG. 105.—Giant water-bug, *Zaitha.*

The members of this family are predaceous. Their fore legs are fitted for seizing prey and resemble somewhat those of the water-scorpions.

These insects can be easily kept in aquaria and are good subjects for study. The outlines already given for the study of other pond insects will afford suggestions for work on these. A striking feature in the life history of many of the giant water-bugs is

that the female fastens her eggs on the top of her own back with a thin layer of waterproof glue, which she secretes for this purpose. Fig. 106 represents a species found in the far West.

FIG. 106.—Female, with eggs, *Serphus*.

The pinned specimens in your collection should be placed after the water-scorpions under a copy of the following label:—

Family BELOSTOMIDÆ (Bel-os-tom'i-dæ).

The Giant Water-bugs.

THE WRIGGLERS (*Field Work*).—The wrigglers, or "wigglers," as they are more commonly called, are so well known that it is hardly necessary to describe their form that they may be recognized. They abound throughout the warmer part of the year in ponds, in ditches choked with fallen leaves, and in pools in swampy places. But usually they are most easily found in exposed receptacles of rain-water, in watering-troughs, and in other sim-

FIG. 107.—A glass of water containing eggs, larvæ, and pupæ of mosquitoes.

ilar places. There are two forms of them: one are the larvæ of mosquitoes, the other the pupæ of the same insects; both are represented in Fig. 107.

Collect some wrigglers and put them in a glass of water where you can observe them. This aquarium should be kept covered when you are not studying the insects in it.

THE LARVÆ OF MOSQUITOES (*School Work*).—In the study of wrigglers begin with the larvæ; these are of the form shown at *a* in Fig. 108.

FIG. 108.—Mosquitoes. *a*, larva; *b*, pupa.

1. Note that when a larva is at rest it hangs from the surface with its head down; several are shown in this position in Fig. 107.

2. Note that when a larva is disturbed it swims away with a wriggling motion or quietly sinks toward the bottom.

3. Note that a larva can sink without any apparent effort, while in order to regain the surface it is forced to exert itself violently. Evidently the body of the insect is heavier than water.

4. Let us see if we can discover the means by which the larva keeps itself at the surface without any effort, although the body is heavier than water.

Note that the true hind end of the body, the last abdominal segment, is not at the surface, but is turned to one side, and that what really reaches the surface is the end of a tube borne by the next-to-the-last segment. This is the breathing-tube of the larva. If the pupil has the use of a microscope, a larva should be mounted on a glass slip and the structure of this breathing-tube examined. It will

be found to bear at its hinder-end a rosette of five platelike lobes; this is shown at *a* in Fig. 109. This rosette can be seen imperfectly with a good lens. When a larva reaches the surface it spreads out the rosette upon the surface film, which buoys it up in the same way that we have seen a needle supported by this film (see experiment 1, page 104). The body of the larva is only slightly heavier than the water, and the buoyant effect of the surface film on the rosette is sufficient to overcome this difference.

FIG. 109.—*a*, end of breathing-tube of larva; *b*, breathing-tube of pupa.

5. Consider the adaptations in structure to the mode of life of this insect: The form of the respiratory tube enables it to rest at the surface of the water, where it can get a supply of air, while the greater weight of the fore end of the body causes it to hang down into the water in a position suited to collecting the minute particles of decaying vegetation scattered through the water and upon which the insect feeds. This position is also one that enables the insect to start quickly on its wriggling journey when alarmed.

6. If the student has the use of a microscope, it will be well for him to make at this point a larger and more detailed figure of a larva than that given above, which was introduced merely to show the general form of these insects in this stage.

THE PUPÆ OF MOSQUITOES (*School Work*).—The larvæ of mosquitoes develop rapidly, and after a few molts change into club-shaped pupæ, the head and thorax being greatly enlarged in this stage. The

general form of the pupæ is shown at *b* in Fig. 108. Usually larvæ and pupæ are found at the same time, but if you have only larvæ you can obtain pupæ by keeping the larvæ in water till they transform.

1. Note and describe the differences between the larvæ and the pupæ in the following respects: The form of the body. The position of the insect when at rest. The number and position of the breathing-tubes. (The structure of a breathing-tube of a pupa, as seen through a microscope, is shown at *b* in Fig. 109.)

2. Note that the pupæ of mosquitoes are active, swimming with a wriggling motion similar to that of the larvæ. It is a very unusual thing for insects that have a complete metamorphosis (see page 35) to be active in the pupa state.

3. Observe the wing-pads on the sides of the thorax, also the leaflike appendages at the tail end of the body, with which the insect swims.

4. If you have an opportunity to do so, study the pupa with a microscope and make a large, detailed drawing of it.

5. How does the pupa make use of the surface film of water?

THE EMERGENCE OF MOSQUITOES.—The pupa state of mosquitoes lasts only a few days, then the skin splits down the back, and the winged mosquito carefully works itself out and cautiously balances itself on the cast skin, using it as a raft, until its wings are hardened so that it can fly away.

Collect many wrigglers, and, keeping them in water, try to observe the emergence of the adult.

ADULT MOSQUITOES.—The form of mosquitoes is very well known, but there are certain mosquitolike insects that are liable to be mistaken for members of this family. Mosquitoes differ from these, however, in having a fringe of scalelike hairs on the margin of the wing and also on each of the wing-veins. Fig.

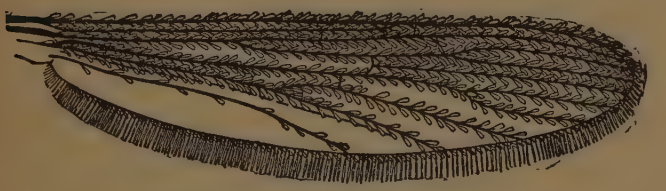


FIG. 110.—Wing of mosquito.

110 represents the wing of a mosquito as seen through a microscope.

The sexes of mosquitoes can be distinguished by the form of the antennæ; at *m* in Fig. 111 is represented the antenna of a male, and *f* the antenna of a female.

FIG. 111. — Antennæ of mosquitoes. *m*, male; *f*, female.

It is only the females that sing and bite; the males are mute and live on the juices of plants.

The eggs are laid side by side in a boat-shaped mass on the surface of the water. One of these is represented floating in Fig. 107. By collecting a mass of this kind and putting it in a vessel of water, the complete life history of these insects can be observed.

Mosquitoes belong to the order of two-winged insects or flies.* Collect some adults and, if you have very slender pins, pin them; if not, mount them on

cardboard points. Copy the following labels, and arrange your specimens under them :—

Order DIPTERA (Dip'te-ra).
The Flies.

Family CULICIDÆ (Cu-lic'i-dæ).
The Mosquitoes.

Write up the life history of a mosquito, and place specimens of the eggs, larvæ, and pupæ in alcohol in your collection with the adults.

INSECTS THAT REST AT THE BOTTOM.

As a rule, it is rather difficult to watch in the field the habits of insects that live at the bottom of ponds; but in most cases these insects can be kept in aquaria, and there studied without difficulty. By searching ponds or the quiet portions of streams, some of these insects may be seen crawling over the bottom, and can then be taken with the hand. But a more rapid way of collecting them is by sweeping the bottom of the pond and submerged plants with an insect net. If the work outlined in the preceding pages has been carried out, it is more than probable that some of these insects are already in your aquaria. If not, seek for them in the field.

THE HABITS OF WATER-BOATMEN (*School Work*).—These are oval, gray and black, mottled bugs, usually less than half an inch in length; they occur in the streams, ponds, and lakes of the whole United States. The characteristic form and markings of these insects are shown in Fig. 112. Very little difficulty will be had in finding these insects in almost any lo-

cality where there are ponds of water, and they are very easily kept in aquaria.

1. Remove a few specimens from the aquarium, and place them in a glass of water in the bottom of which there is a layer of gravel or small pebbles. If several specimens are placed in the glass, some of them may come to rest near enough the side of the glass so that they may be studied with a lens.

FIG. 112.

2. Note that the favorite attitude of a water-boatman is clinging to a pebble at the bottom of the aquarium by the tips of the middle legs, with the fore legs bent up under the head and the hind legs stretched out sidewise like oars. This is a very different attitude from that assumed by their near relatives, the back-swimmers.

3. Note that there is a thick layer of air covering the entire belly or ventral side of the body. Sometimes this layer of air extends down the legs nearly or quite to the ends of the coxæ, and often there is a strip of air on the outside of the outer edge of each upper wing. The spaces between the head and prothorax, the prothorax and mesothorax, and between the wings and abdomen are also filled with air. These masses of air can be seen when the insect bends its body.

4. By watching these insects carefully, you will be able to see that sometimes one will lift its wings slightly, thus drawing the air from the ventral side of the body up under the wings; and, on the other

hand, they frequently rub their hind legs down their backs, thus forcing the air from under the wings to the ventral surface of the body.

5. Note that while a water-boatman is resting near the bottom of the aquarium, it frequently moves its oarlike hind legs backward with a quick sweeping motion, causing a current of water to flow over the layer of air on the ventral side of the body.

Although the water-boatmen breathe air, which they carry with them in a way very similar to that of the back-swimmers, they are able to remain under water without going to the surface to renew the supply of air for a very long period. This, I think, is explained by the fact that the air on the lower side of the body and along the outer edge of the wing-covers is in direct contact with the water, so that it can be purified by the air that is mixed with the water. And probably it is to insure this purification of the layer of air that the insect causes a current of water to flow over it by the sweeping motion of its hind legs. This also explains the reason for forcing the air out from under the wings and drawing it back again.

Sometimes, however, the insects dart to the surface and return to the bottom as if going after a fresh supply of air; but the movement is so rapid and the stay at the surface is so short that I have been unable to determine the manner of taking the air.

6. Observe the mode of life of these insects as completely as possible, and write an account of them.

THE STRUCTURE OF WATER-BOATMEN (*School Work*).—Kill and pin some specimens, and study their structure.

1. Note that the head overlaps the prothorax instead of being inserted in it, as is usually the case with insects.

2. Observe the very large, three-cornered eyes. The antennæ are very small, and are concealed under the backward-projecting edge of the side of the head.

3. Observe the lower part of the front of the head; it tapers to a blunt point, but it is not prolonged into a slender beak, as is usual with bugs; near the tip of the head there is a small opening, through which the sucking mouth-parts are pushed when in use.

4. The prothorax is conspicuous above, and is marked by transverse stripes; on the sides it is very short, and below it is almost completely covered by the head; this brings the fore legs very near to the mouth.

5. Make a drawing of one of the fore legs; note that the tarsus consists of a single segment, is scoop-like in form, and bears a comblike fringe of bristles.

6. Make a drawing of a middle leg, and note the very long, slender tarsal claws. What is the use of these claws?

7. Make a drawing of a hind leg. What are these legs fitted for?

8. Study the lower side of the abdomen of several specimens. In the females the segments are of the usual form, but in the males some of them, and especially the last four, are very unsymmetrical, being, upon one side, broken into irregular-shaped fragments. The cause of this is not known.

9. Indicate by labels the sexes of your pinned specimens.

10. Place the pinned specimens in your collection with the Hemiptera under a copy of the following label:—

Family Corisidæ (Co-ris'i-dæ).

The Water-boatmen.

The Nymphs of Damsel-flies (*Field Work*).—The nymphs of damsel-flies are truly aquatic, having gill-like organs which enable them to live in water without coming to the surface from time to time for a supply of air. They may be found in those ponds or streams about which the adults fly, and are most abundant among the stems of submerged plants. Fig. 113 will enable you to recognize these insects when found.

Fig. 113.—Nymph of damsel-fly.

Collect specimens of these nymphs and place them in aquaria for study.

The Habits and Structure of the Nymphs of Damsel-flies (*School Work*).—The nymphs of damsel-flies are easily reared in aquaria in which the water is kept pure by growing plants. Frequently tiny ones will appear in such aquaria from eggs that were in the stems of the plants when they were collected. In such cases it is easy to watch the entire life history of the insect after it leaves the egg.

We will not outline such a study, for the pupil who has made the observations on pond life already indicated will be able to direct his own studies; and independent original observations are much more

enjoyable than prescribed work. We will, however, explain two striking peculiarities in the structure of these insects:

1. Remove the nymph from the water and examine its mouth-parts. The lower side of the head will be seen to be covered by a broad flap; this is the greatly developed lower lip or labium, and is termed in these insects the mask. With a pin lift the end of the mask away from the head, and observe that it is very long and is hinged in such a way that it can be pushed out a considerable distance in front of the head. Note also that it is furnished with hooks at the end. This is the organ by which the nymph seizes its prey. Try to observe the nymphs in your aquarium catch other insects.

A similar organ is possessed by the nymphs of dragon-flies, and is represented in Fig. 115.

2. Observe the leaflike organs at the hind end of the body. These are the tracheal gills, the organs by means of which the insect breathes during its life in the water. Fig. 114 represents a tracheal gill of a damsel-fly greatly enlarged. These organs are called tracheal gills because the tracheæ or air-vessels extend into them, and the air contained in the tracheæ is purified by the water (or rather by the air in the water) that bathes the gills. While with true gills, as those of fishes and lobsters, etc., the gill contains vessels carrying blood to be purified.

FIG. 114.

3. Preserve specimens of nymphs of damsel-flies in alcohol and put them in your collection with the adults.

4. Write an account of what you have learned about these insects.

THE HABITS AND STRUCTURE OF THE NYMPHS OF DRAGON-FLIES (*Field and School Work*).—The nymphs of dragon-flies are found in the same situations as those of damsel-flies; they are also found crawling over the bottoms of ponds and streams where there are no plants growing. They vary greatly in form, some being slender while others are very broad. They resemble the nymphs of damsel-flies in having a mask and in their use of this organ; but they differ in lacking the external tracheal gills. Fig. 115 represents one of these nymphs.

Collect specimens of these nymphs and place them in aquaria for study. Also preserve some in alcohol in your collection with the adult dragon-flies. When collecting these, search for cast skins along the shores of the pond or stream. Preserve specimens of the cast skins in your collection.

FIG. 115.

We will call attention to only one feature in the structure and habits of these creatures, leaving the pupil to discover other things for himself:

The nymphs of dragon-flies possess tracheal gills of very unusual form. These are situated within the body, and consist of a large number of tracheæ ramifying in the walls of the hind part of the intestine —the rectum. The nymph draws water into this part of the intestine through the opening at the hind end of the body; and this water, bathing the walls of the rectum, purifies the air in the tracheæ

in the same way that the air in the tracheæ of an ordinary tracheal gill is purified. By watching a living specimen it can be seen to alternately draw in the water and force it out again.

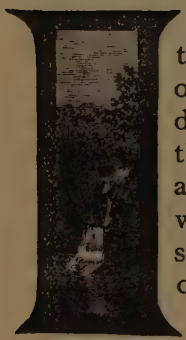
This arrangement serves as an organ of locomotion as well as an organ of respiration. For the insect, by suddenly forcing out the water from the rectum, can cause itself to shoot forward. The jet of water forced out from the rectum when the insect jumps forward is most easily seen when the insect is on the bottom of the aquarium; in such a case the fine dirt will be disturbed by it for a considerable distance back of the insect.

If you can find a large number of nymphs of dragon-flies, do so, and, keeping them in aquaria, try to observe the emergence of the adult. Of this Tennyson wrote:

> To-day I saw the dragon-fly
> Come from the wells where he did lie,
> An inner impulse rent the veil
> Of his old husk; from head to tail
> Came out clear plates of sapphire mail.
> He dried his wings: like gauze they grew,
> Through crofts and pastures wet with dew
> A living flash of light he flew.

CHAPTER V.

BROOK LIFE.



N a deep ravine, where a hill stream tumbles down a stairway of rocks, is one of our favorite resorts on Saturdays. A dense forest growth covers the sides of the ravine, and shuts out all the world besides; but at midday, when the sun shines brightly, the light streams down through the narrow opening above the creek. This is the time to watch the ways of the creatures clinging to the rocks in the rapids, or living in the quiet pools below. Many a holiday have we waded up this stream, bottles and lens in hand, coaxing Nature to yield up some of her secrets.

Here we have watched the caddice-worms drag their log houses over the bottoms of the pools; here the brinks of the falls bear great patches of a living carpet of wriggling black-fly larvæ; and here we discovered how the net-winged midges leave the water, unfold their wings, and take flight. It is a rich collecting field; the cool, pure water of the brook and the rush of the torrents affording a home

PLATE VI. A BROOK.

for many creatures that can not live in the warmer and more quiet streams of the valley below.

In the following pages are mentioned some of the insects that may be found in similar streams—that is, in streams flowing rapidly over stones. Most of these insects occur rarely or not at all in quiet, sluggish streams, flowing over sandy bottoms, through level stretches of country. In such streams are found the insects described in the chapter on Pond Life.

In our hill stream, too, there occur many of the pond insects, for during its course there are quiet bays and broad, still waters, which seem perfectly suited to their needs.

Little brook, sing to me:
Sing about a bumblebee
That tumbled from a lily-bell, and grumbled mumblingly
Because he wet the film
Of his wings, and had to swim,
While the water-bugs raced round and laughed at him!

Little brook, sing a song
Of a leaf that sailed along
Down the golden-braided center of your current swift and strong,
And a dragon-fly that lit
On the tilting rim of it,
And rode away and wasn't scared a bit.

*James Whitcomb Riley.**

INSECTS THAT LIVE BENEATH STONES IN RAPIDS.

There is no collecting field that is more certain to yield returns than the bed of a rapidly flowing stream of pure water. Lift the stones from such a

* From Old-fashioned Roses, by permission of the Bowen-Merrill Co.

stream at any season of the year and you will find nymphs and larvæ of various kinds clinging to their lower surface. If before lifting the stones you will place a net in the stream just below them, other insects that live beneath the stones will be swept into it by the current.

A great variety of insects live in such places, the kinds differing in different localities. But there are certain families that are almost sure to be represented in any rapidly flowing stream; they are the stone-flies, the May-flies, and the caddice-worms. These and a few others are described below.

Most of these insects are not easily kept in aquaria without running water. But if you can place an aquarium under a faucet, and keep the water from overflowing by the use of a constant-level siphon (see page 331), you may be able to preserve living specimens for study.

If you are unable to do this, study the insects as well as you can in the field, and bring back specimens for your collection and for a study of their structure.

THE NYMPHS OF STONE-FLIES (*Field and School Work*).—In most localities the insects that occur in greatest numbers on the lower side of stones in the beds of streams are the nymphs of stone-flies, and it was probably this fact that suggested their common name. Usually the first stone lifted from a riff will be found to bear several of these insects clinging to it, or scurrying over its surface in their efforts to escape. When at rest the very flat body is closely applied to the stone, while the legs, antennæ, and caudal setæ radiate from it on the surface of the

stone. In our common forms there is a tuft of hair-like tracheal gills just behind the base of each leg, and the more mature individuals have conspicuous wing-pads (Fig. 116). These general characteristics will enable the pupil to recognize these insects. Specimens should be collected and taken to school for a more careful study of their structure. Look also for empty nymph skins; these will be found clinging to stones and other objects on the shores of the stream, where they were left when the adults emerged.

FIG. 116.—Nymph of stone-fly.

Pin the empty nymph skins and preserve the nymphs in alcohol. Put both in your collection with the adult stone-flies (see page 103).

In the study of the structure of these insects note the following: The nymphs resemble the adults to a considerable degree, except that they lack wings. The order *Plecoptera*, or stone-flies, is a good example of those orders, the members of which undergo an incomplete metamorphosis. The body is greatly flattened; in this way the insect is well fitted for creeping under stones. The legs are flattened and fringed with hairs, fitting the insect for swimming as well as for creeping. The tarsi are each furnished with *two* claws. The organs of special sense are well developed, there being large compound eyes, three simple eyes, and long antennæ. The mouth is fur-

nished with strong, toothed mandibles (it is sometimes necessary to cut away the upper lip in order to see them well), and the caudal end of the body is furnished with two large setæ. The number and position of the tufts of tracheal gills differ in different species.

The nymphs of stone-flies are carnivorous.

THE NYMPHS OF MAY-FLIES (*Field and School Work*).—These are also found beneath stones in the beds of rapidly flowing streams, but they also occur in many other situations. Some live in the banks of streams, where they excavate burrows for shelter; others live in slowly moving waters and conceal themselves by covering the body with mud; and still others swim among water plants. But in regions where there are rapidly flowing streams, those that live under stones will be most easily found.

As a rule, the body is not flattened to so great an extent as with the nymphs of stone-flies; the tracheal gills are usually more or less platelike in form, although sometimes they are threadlike and tufted; and the tarsi end in a single claw. Fig. 117 represents one of our most common species.

FIG. 117.—Nymph of a May-fly.

Study the structure of a nymph, and compare it with that of the nymph of a stone-fly.

Preserve specimens in alcohol, and put them in your collection with the adult May-flies (see page 101).

THE CADDICE-WORMS (*Field and School Work*).—When the writer was a lad, before he had heard of

Nature study—before the study of insects except as a part of zoölogy was taught in any school in this country—he began his study of caddice-worms. It was not a thorough study—in fact, he would have been surprised to have heard it called study at all. To him it was fun, after a long tussle with a hard Latin lesson, to run over the long bridge across the river and on to the swamp near the lake where the Azaleas blossomed, and to lie face down on the bank of a stream and watch the curious worms that had tiny log houses about their bodies.

It was his first introduction to a field of study that has since happily occupied the greater part of his time for several decades. Probably for this reason he always experiences a thrill of pleasure when he is permitted to introduce these little architects to other Nature-loving youngsters.

Fig. 118.

This was a sluggish stream, and the caddice-worms found there built cases of fragments of partly decayed wood, like that shown in Fig. 118. Later, in another quiet stream where grass was growing in the water, there were found other caddice-worms, which built cases having a still greater resemblance to log houses. These cases were composed of tiny lengths of grass laid crosswise (Fig. 119). They are rough-appearing structures, but within they are smooth and lined with silk—an excellent protection to the soft-bodied larvæ that occupy them.

Fig. 119.

Caddice-worms, like either of these described

above, can be kept in aquaria, and are excellent subjects for study.

In swiftly flowing streams, and especially in those in which the water is cool, there may be found many other kinds. Several of these build cases of small stones or grains of sand. Some of the cases are very regular in form; others consist of a central tube with large stones fastened on two sides of it (Fig. 120);

FIG. 120.

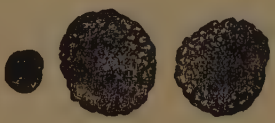


FIG. 121.

FIG. 122.

and one kind, built of fine sand, is coiled so as to resemble the shell of a snail (Fig. 121).

In all of these the material of which the case is made is fastened together by silk, which the larvæ spin from the mouth in the same manner as caterpillars. In some species the case is composed entirely of silk. Fig. 122 represents the form of such a case made by a larva that lives among eel-grass in a lake.

Before transforming to pupæ, the caddice-worms partly close their cases so as to keep out intruders, but openings are left for the inflow of water for breathing.

The adults are known as caddice-flies; they are mothlike insects, which are often attracted to lights at night. Fig. 68, page 79, represents one of them.

Collect as many kinds of caddice-worms as possible. Keep alive some of those that will live in aquaria, and study their habits.

Remove some from their cases, and study their

structure. Note especially the following: The great length of the legs, which enables the larva to pull itself along without exposing much of its body; the firmer covering of the fore part of the body which is exposed while the insect is walking; the softer texture and paler color of the protected parts of the body; the number, form, and position of the tracheal gills; and the hooks at the hind end of the body by which the larva holds itself within its case.

Preserve larvæ with their cases in alcohol, and mount empty cases on cards. Try to rear pupæ and adults from larvæ kept in aquaria.

Place specimens of larvæ, cases, pupæ, and adults in your collection under a copy of the following label:—

Order TRICHOPTERA (Tri-chop'te-ra).

The Caddice-flies or Caddice-worms.

Write an account of your observations on these insects, and illustrate it with sketches of their cases.

THE NET-BUILDING CADDICE-WORMS (*Field and School Work*).—In lifting stones from a stream where the current flows swiftly, the collector often finds attached to the lower side of the stones little masses of pebbles which are fastened to each other and to the larger stone by threads of silk. These are the homes of the net-building caddice-worms.

Pull these rude habitations apart and the owners will be found in more or less perfect tubes of silk. Very little respect for the architectural skill of these builders is commanded by their dwellings. But if one looks a little farther something will be found that is sure to excite admiration. The dweller with-

in this rude retreat is a fisherman, and stretched between two stones near-by can be seen his net.

This is made of silk. It is usually funnel-shaped, opening up-stream, and in the center of it there is a portion composed of threads of silk extending in two directions at right angles to each other, so as to form meshes of surprising regularity. It is as if a spider had stretched a small web in the water where the current is swiftest (Fig. 123).

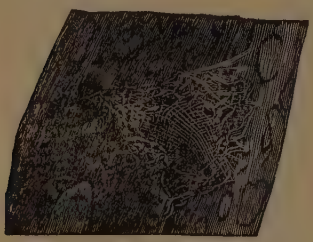


FIG. 123.—Net of a net-building caddice-worm.

These nets occur in rapids between stones, but in many places they are to be found in greater numbers along the brinks of falls. Here they are built upon the surface of the rock, in the form of semi-elliptical cups, which are kept distended by the current. Much of the coating of dirt with which these rocks are clothed in summer is due to its being caught in these nets.

It is usually difficult to procure specimens of these nets for preservation; sometimes, however, one can be found attached to the surface of a single small stone or to a piece of wood in such a way that it can be removed from the water without injury to it.

Find some net-building caddice-worms and learn all you can regarding their ways; collect specimens for your collection and for study; compare their structure with that of other caddice-worms; preserve specimens of larvæ in alcohol; and dry, if possible, some of their nests and nets.

Write an account of these insects.

THE WATER-PENNIES (*Field Work*).—These are strange larvæ, which are rarely recognized as insects by the young collector. They are very flat, circular in outline, and about five sixteenths of an inch in diameter. They are found clinging to the lower surface of stones in rapid streams. Fig. 124 represents one greatly enlarged. They are larvæ of beetles of the genus *Psephenus* (*Pse-phe'nus*), and are merely mentioned here so that the student of brook life may know what they are.

FIG. 124.—A water-penny.

THE DOBSON OR HORNED CORYDALIS (*Field Work*).—If a net or a wire screen be held with one edge close to the bottom below some stones lifted with a hoe or garden rake, many of the insects living under the stones will be swept into the net or upon the screen, and can thus be captured. One of the insects that is often caught in this way is the dobson, the ugly creature represented by Fig. 125.

FIG. 125.—The dobson.

This larva is well known in many parts of the United States, as it is used extensively by anglers for bait, especially for bass, and in spite of its disagreeable appearance it is in some respects very interesting to students of Nature study.

It will not thrive in an ordinary aquarium, but it can be kept alive in one through which there is a current of well-aërated water flowing. If such an aquarium is lacking, specimens can be kept alive on damp sand or in a box with freshly cut grass, for this is a truly amphibious species.

As this insect lives nearly three years in the larval state, larvæ can be found at any season of the year. In the latter part of May or early in June the full-grown larvæ leave the water, and each makes a cell under a stone or some other object on or near the bank of the stream. Here they soon change to pupæ. These are white and have prominent wing-pads. In about a month after the larva leaves the water the adult insect appears. Fig. 126 represents the male, which has remarkably long mandibles. The female resembles the male, except that the mandibles are comparatively short. Soon after the adults appear the eggs are laid. These are attached to stones or other objects overhanging the water; they are laid in blotchlike masses which are chalky-white in color, and measure from half an inch to nearly an

FIG. 126.—The adult dobson or horned Corydalis, male.

inch in diameter. A single mass contains from two thousand to three thousand eggs. When the larvæ hatch they at once find their way into the water, where they remain until full grown.

The best time to study this insect is late in the spring and early in the summer, for at this season all stages of it can be found. Try to get larvæ, pupæ, adults, and eggs, and preserve them in your collection under a copy of the following label:—

Order NEUROPTERA (Neu-rop'te-ra).

Family SIALIDÆ (Si-al'i-dæ).

The adult dobson is known as the horned Corydalis, its scientific name being *Corydalis cornuta*.

THE STRUCTURE OF THE DOBSON (*School Work*).—Put a larva in a cyanide bottle one or two hours before it is needed for study, as it requires considerable time to kill these insects.

1. Lay the specimen on its back and make a drawing of the ventral surface.

2. Name the parts and appendages of the body shown in this view. The long, tapering appendages on the sides of the abdomen may be termed the *lateral filaments;* the tufts of hairlike appendages near the bases of the lateral filaments are *tracheal gills*, and at the hind end of the body there is a pair of *prolegs*. Each proleg is furnished with a pair of claws.

Note that in addition to the tracheal gills this larva has well-developed spiracles. Make a drawing of a spiracle as seen through a lens. Note especially the lid by which the opening of the spiracle is closed. State the number of spiracles and the position of

each pair. Consider how well fitted this insect is both for life in the water and on the land.

A more detailed account of the structure of this larva is given in The Elements of Insect Anatomy, by Comstock and Kellogg.

THE NEAR RELATIVES OF THE DOBSON OR CORYDALIS (*Field Work*).—In searching for the dobson the pupil is apt to find certain other members of the same family which live in similar situations. Some of these resemble *Corydalis* very closely, except that they are smaller when full grown and do not have tufts of tracheal gills; these belong to the genus *Chauliodes* (*Chau-li'o-des*). A still smaller larva which is similar in form and also lacks tracheal gills is *Sialis* (*Si'a-lis*); this differs from both of the preceding in having at the hind end of the body a long, tapering appendage instead of a pair of prolegs. Place any specimens that you may get of either of these in your collection under the family *Sialidæ* (see page 155).

INSECTS THAT LIVE EXPOSED IN TORRENTS.

There are many insects that find in rapids places best fitted for their existence, but most of these are more or less protected from the rush of the water by the fact that they live beneath stones. Some insects, however, scorn any protection, but live exposed where the water flows the swiftest; two of these are mentioned below.

THE BLACK-FLIES (*Field Work*).—The larvæ of the black-flies should be sought in streams flowing down steep descents. If present, they are easily found, for they occur clustered together in large numbers, forming a black coating over the rocks. They prefer the

brinks of falls and places where the slanting bed-rock is washed clean by a swift flow of water, but sometimes they cling to pieces of wood or small stones that are firmly fixed in the rapids.

When the larvæ are fully grown they spin boot-shaped cocoons within which the pupa state is passed; these are firmly fastened to the rock upon which the larvæ lived. In Fig. 127 there are represented a larva and a cocoon.

FIG. 127.—Cocoon and larva of a black-fly.

1. Find a cluster of larvæ and take notes on the following: The way in which they keep their place in the swift current. (It is the tail end by which they are usually fastened to rock.) Their method of locomotion, and the action of the fan-shaped organs attached to the head.

2. Collect larvæ and cocoons and try to keep them alive in water. These insects can not be reared in aquaria unless they are placed under a jet of water, but they can be kept alive several hours, thus giving some opportunity for watching their habits in confinement.

3. Look for the eggs of the black-flies. These are yellowish or brownish and occur in patches in situations similar to those inhabited by the larvæ.

4. Look also for adults. These occur in swarms, hovering over the brinks of falls and dashing back and forth through the spray. Sometimes they may be seen darting into the water and out again; at such times they are laying their eggs.

Fig. 128 represents one of these flies somewhat

enlarged, and Fig. 129 represents an antenna much more enlarged. The peculiar venation of the wings is sufficient to distinguish black-flies from all others.

FIG. 128.

FIG. 129.

THE BLACK-FLIES (*School Work*).—Prepare for your collection as complete a series as possible of the different stages of these insects, pinning the flies and preserving the eggs, larvæ, and cocoons with pupæ in alcohol. Place them with other Diptera under a copy of the following label:—

Family SIMULIIDÆ (Sim-u-li'i-dæ).

The Black-flies.

Watch living larvæ in a glass of water and observe the following: The disklike sucker, fringed with hooks at the caudal end of the body. The fleshy proleg situated just back of the head; this ends in a sucker fringed with hooks. The thread of silk spun from the mouth. The fan-shaped organs borne by the head. And the three delicate, much-branched tracheal gills, which are pushed out from between the last two abdominal segments.

Write an account of what you have learned regarding black-flies, including a description of the methods of locomotion of the larvæ and the probable method by which the larvæ obtain their food. It has been found by examining the stomachs of these larvæ that they feed on microscopic aquatic plants and bits of tissue of larger plants.

THE NET-WINGED MIDGES (*Field and School Work*).—These insects occur in situations similar to those

inhabited by the black-flies, but as they are comparatively rare insects they are merely mentioned here.

In Fig. 130 *a* represents a larva seen from above, *b* a larva seen from below, and *c* a side view of the pupa.

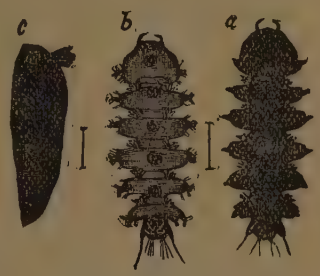


FIG. 130. — Net-winged midges; *a*, larva, dorsal view; *b*, larva, ventral view; *c*, puparium.

As these are the strangest of all insect larvæ they should be carefully studied if found. A full account of their habits and transformations is given in our Manual for the Study of Insects. They belong to the order Diptera and to the family BLEPHAROCERIDÆ (Bleph-a-ro-cer'i-dæ).

INSECTS OF BROOKSIDES.

In the study of brook life the pupil will hardly fail to observe many insects about the shores of the streams. The presence of the greater part of them in such situations is not due to the proximity of water, but is largely a matter of chance. Any forest, orchard, or roadside insect may be found near a brook if its proper food occurs there. Some of these insects are described in subsequent chapters. Here mention is made of a few of those that prefer the vicinity of water and are rarely found elsewhere.

FIG. 131.

THE SHORE-BUGS (*Field and School Work*). —These abound in the vicinity of streams and lakes and upon damp soils. They are small bugs, of dark colors with white or yellow markings, and with long

antennæ. Fig. 131 will aid in recognizing them. The shore-bugs take flight quickly when disturbed, but alight after flying a short distance; some species dig burrows and live for a part of the time beneath the ground. Collect specimens and put them in your collection under a copy of the following label:—

Family SALDIDÆ (Sal'di-dæ).

The Shore-bugs.

THE TOAD-SHAPED BUGS (*Field and School Work*).—There is sometimes found on the margins of streams or in marshes where the soil is moist a curious bug, which, on account of its short and broad body and projecting eyes, reminds one of a toad (Fig. 132). If you find specimens of these, observe the color of the soil upon which they are found and compare it with that of the insects, for this species exhibits considerable variation in coloring, and its colors are usually protective.

FIG. 132.

The toad-shaped bugs belong to the order Hemiptera. Label your specimens as follows:—

Family GALGULIDÆ (Gal-gu'li-dæ).

The Toad-shaped Bugs.

THE PINE-CONE WILLOW-GALL (*Field and School Work*).—The wanderer by the brookside often sees a crop of cones borne by willows, and if he is careless he is apt to pass them by, thinking that they, like the cones of pines and spruces, contain the seeds of the plant. But the observant student knows that the seeds of willows are borne in catkins, which differ greatly in shape from these conelike growths.

These cone-shaped objects belong to that class of vegetable growths termed galls. There are very many kinds of these; and upon some plants, as oaks, for example, they are very abundant.

Galls are produced by insects in this way. The female gall-producing insect stings the plant and lays an egg in the wound. It is believed that in some cases there is deposited with the egg a drop of poison, which causes the growth of the gall. But in other cases the gall does not begin to develop until the larva hatches from the egg and begins to feed upon the tissue of the plant. Evidently if there is a poison in such cases it must be secreted by the larva. The explanation of why galls grow is not yet clear; but we know this much, that each species of gall-making insect makes a particular kind of gall. Hence one versed in this subject can tell by the form and structure of a gall what species of insect produced it. The gall serves as a home and food for the larva developed within it.

FIG. 133.—The pine-cone willow-gall.

Let us return to the pine-cone willow-gall (Fig. 133). This differs in shape and in the manner of its growth from most galls. (Other types of galls will be described in later

chapters.) It is produced by a small gall-gnat, which lays an egg in the tip of a branch of willow. A maggot hatches from this egg and lives in the heart of the bud, which ceases to grow in length; but, strangely enough, leaves continue to be developed, and they, crowded together, form the cone-shaped gall.

Collect specimens of the pine-cone willow-gall and, splitting them open in the middle, find the larvæ that produced them.

In early spring the adult gall-gnats can be reared by keeping the galls in breeding cages.

There is a guest gall-gnat that lays its eggs between the scales of the pine-cone willow-gall, and the larvæ hatched from these develop in this place. Seek for specimens of these larvæ, and in early spring try to breed the adults. Both of these gall-gnats pass the winter in the larval state within the galls. The larvæ can be found within the galls at any time during the summer, fall, or winter; but in order to breed the adults, it is best to leave the galls on the plants till early spring.

There are several kinds of insects, among them certain long-horned grasshoppers, that deposit their eggs between the leaves of the pine-cone willow-gall; the young, however, leave the galls as soon as they are hatched.

Gall-making species are found in several of the orders of insects. The two gall-gnats mentioned here belong to the order Diptera. Place specimens in your collection with other Diptera under a copy of the following label:—

Family CECIDOMYIIDÆ (Cec-i-do-my-i'i-dæ).

The Gall-gnats.

THE ALDER-BLIGHT (*Field and School Work*).—One often finds on the trunks and branches of alders growing on the margins of streams large patches of snowy-white matter. These patches are composed of many insects crowded together and covered with a downy excretion. Such insects are known as woolly-aphids. There are several kinds of common woolly-aphids. That which lives on the alder is known as the alder-blight, another kind living on beech trees is called the beech-tree blight, and a third kind, infesting apple trees, is the woolly-aphis-of-the-apple. All of these secrete large quantities of honey-dew.

Each aphid has its beak inserted into the bark of the infested tree. By cutting off a section of an infested branch and putting it in a cyanide bottle, the insects can be killed, and most of them will remain clinging to the branch. It can then be pinned into the collection. The aphids belong to the order Hemiptera; place specimens under the following label:—

Family APHIDIDÆ (A-phid'i-dæ).
The Plant-lice or Aphids (*Aph'ids*).

THE WANDERER (*Field and School Work*).—The name wanderer has been applied to a butterfly (Fig. 134) that is found only in limited localities, although it occurs from Maine to Florida and westward to Kansas. It prefers the borders of streams and marshy places where alder grows; and now that its life history is known, this fact is explained. The caterpillars of nearly all but-

FIG. 134.—The wanderer.

terflies feed on plants, but the larva of this species is truly carnivorous, feeding on the woolly-aphids known as the alder-blight.

If the alder-blight is common in your locality, search colonies of it for the larvæ of this butterfly. They will be found burrowing through the downy mass, and their paths will be marked by the remains of their victims. They resemble grubs more than ordinary caterpillars, and are more or less covered with the white excretion of the plant-lice. Their legs and prolegs are short and small, allowing the body to be closely pressed to the bark of the branch. By collecting these caterpillars and feeding them with the alder-blight, the transformations of the butterfly can be easily observed. If you do this, save specimens of larvæ, pupæ, pupa skins, and adults for your collection. This species should be labeled as follows:—

Order LEPIDOPTERA (Lep-i-dop'te-ra).

The Moths, the Skippers, and the Butterflies.

Family LYCÆNIDÆ (Ly-cæn'i-dæ).

The Gossamer-winged Butterflies.

THE GROUSE-LOCUSTS (*Field and School Work*).—There is a group of small locusts the members of which are remarkable for the shape of the pronotum. This projects backward like a little roof over the wings, and often extends beyond the end of the abdomen (Fig. 135). With these insects the fore wings are in the shape of small, rough scales, the hind wings being protected by the pronotum.

FIG. 135. A grouse-locust.

The grouse-locusts are commonly found in low, wet places and on the borders of streams. They prefer the broad gravelly stretches where there is little or no vegetation, the low banks that are swept by the water when the streams are high. They vary greatly in color, their color being usually similar to that of the soil on which they live. They are very active, and hence difficult to catch without the use of a net. In studying these insects in the field note especially the protective nature of their colors. Prepare one or more specimens for your collection by spreading the wings so as to show the relative size of the fore and hind wings.

Label them as follows:—

Order ORTHOPTERA (Or-thop'te-ra).

Cockroaches, Crickets, Grasshoppers, and Others.

Family ACRIDIDÆ (A-crid'i-dæ).

The Locusts, or Short-horned Grasshoppers.

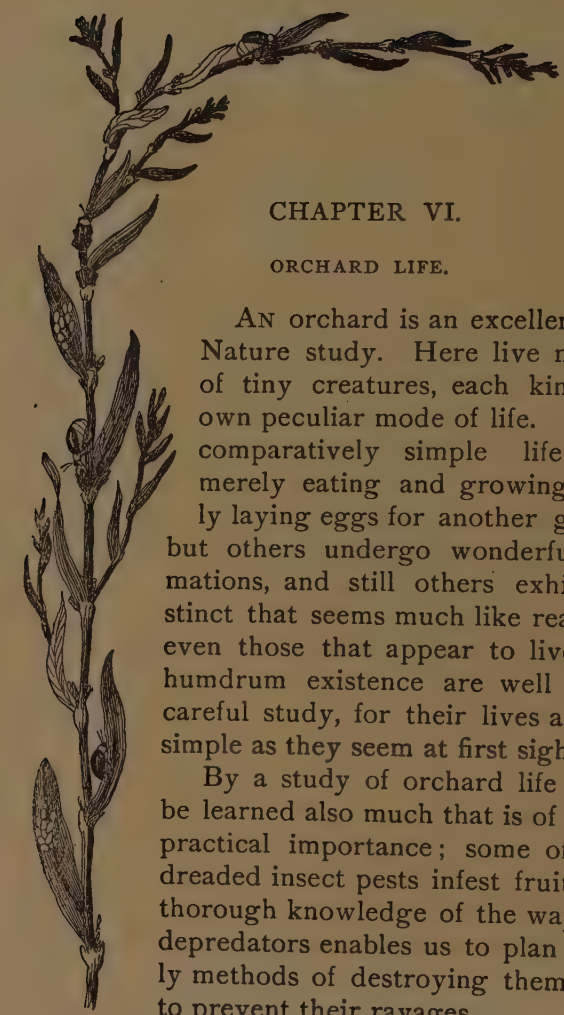


FIG. 136. Knotgrass and the knotgrass beetle, *Gastroidea polygoni*.

CHAPTER VI.

ORCHARD LIFE.

AN orchard is an excellent place for Nature study. Here live many kinds of tiny creatures, each kind with its own peculiar mode of life. Some have comparatively simple life histories, merely eating and growing and finally laying eggs for another generation; but others undergo wonderful transformations, and still others exhibit an instinct that seems much like reason. And even those that appear to live the most humdrum existence are well worthy of careful study, for their lives are never as simple as they seem at first sight.

By a study of orchard life there may be learned also much that is of immediate practical importance; some of the most dreaded insect pests infest fruit trees. A thorough knowledge of the ways of these depredators enables us to plan successfully methods of destroying them, and thus to prevent their ravages.

To carry on this study it is not necessary to go to a large orchard. Except in a city, almost every dwelling-house has

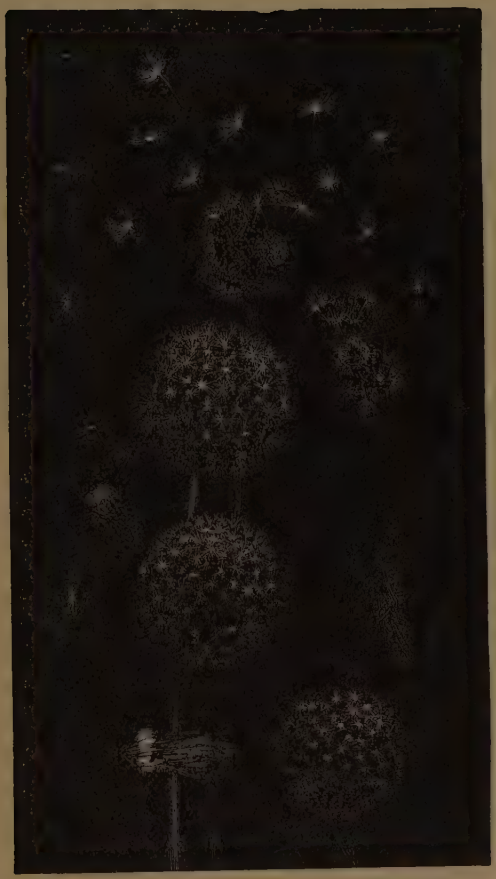


PLATE VII. DANDELIONS AND A LOCUST.

some fruit trees about it, and these are sure to be infested by some of the insects described in this chapter. And the boys and girls that live in cities can find fruit trees with a little effort.

This chapter is restricted to insects infesting fruit trees. Many other kinds of insects may be found on grass and other herbage about orchards; some of these are described in the chapter on Roadside Life.

Under the high-top sweeting,
Many a playmate came to share
The sports of our merry meeting:
Zigzag butterflies, many a pair,
Doubled and danced in the sunny air;
The yellow wasp was a visitor there;
The cricket chirped from his grassy lair;
Even the squirrel would sometimes dare
Look down upon us, with curious stare;
The bees plied fearless their honeyed care
Almost beside us, nor seemed aware
Of human presence; and when the glare
Of day was done, and the eve was fair,
The fireflies glimmered everywhere,
Like diamond-sparkles in beauty's hair,
In the boughs of the high-top sweeting.
The humming-bird, with his gem-bright eye,
Paused there to sip the clover,
Or whizzed like a rifle-bullet by;
The katydid, with its rasping dry,
Made forever the same reply,
Which laughing voices would still deny;
And the beautiful four-winged dragon-fly
Darted among us, now low, now high,
And we sprang aside with a startled cry,
Fearing the fancied savagery
Of the harmless and playful rover.

The flying grasshopper clacked his wings,
Like castanets gayly beating;
The toad hopped by us, with jolting springs;
The yellow spider that spins and swings
Swayed on its ladder of silken strings;
The shy cicada, whose noon-voice rings
So piercing shrill that it almost stings
The sense of hearing, and all the things
Which the fervid northern summer brings—
The world that buzzes and crawls and sings—
Were friends of the high-top sweeting.

*Elizabeth Akers.**

INSECTS INFESTING FOLIAGE.

THE APPLE-TREE TENT-CATERPILLAR (*Field and School Work*).—In early spring, as soon as the leaves begin to expand, conspicuous webs may be found on the branches of apple and other trees. The beginning of such a web is represented in the upper part of Fig. 137. These webs are the "tents" of the apple-tree tent-caterpillar—an insect that is social while in the caterpillar state. Each colony consists of the larvæ that have hatched from a cluster of eggs deposited by a moth on a twig near the place where the web is afterward built. Such a cluster of eggs is represented above the web in the figure. Usually, however, the tent is built much farther from the egg-cluster than is shown here.

1. Search for egg-clusters on the twigs of apple before the leaves appear; they can be found at any time during the winter or early spring.

2. If egg-clusters are found, examine them from

* From The High-top Sweeting, by permission of Messrs. Charles Scribner's Sons.

day to day and ascertain the date of hatching of the larvæ.

3. If the larvæ hatch before the leaf-buds open, ascertain upon what the larvæ feed at this time.

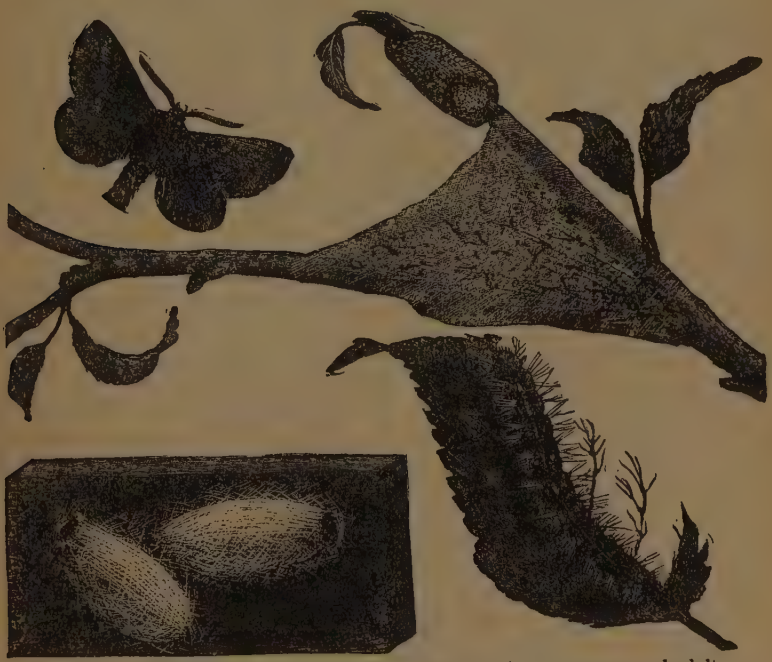


FIG. 137.—The apple-tree tent-caterpillar, eggs, tent, larva, cocoons, and adult.

4. If egg-clusters are not found, search for webs. Upon what kinds of trees other than apple can these be found?

5. If possible, find a specimen in a convenient place to study—where it can be examined daily. If none is found near the school or the home of the pupil, or near some street between the two, cut off a

branch bearing a tent, and tie it to a branch of another tree of the same kind in a convenient place.

6. Describe the position, form, and structure of one of these tents. Of what is it made? Where does the substance of which it is made come from? How is the tent held in place? How is it increased in size? Make a picture of a tent.

7. Describe one of the caterpillars that lives in this tent (see page 325).

8. Upon what do the caterpillars feed? At what time of the day do they feed? How far do they go for their food?

9. Are the paths over which the caterpillars go to and from their food marked in any way? If so, how?

10. The way in which this pest is usually fought is by destroying the caterpillars in their tents. Can this be done better at one time of day than another? If so, when?

11. Search for the remains of the cluster of eggs from which a colony of tent-caterpillars have hatched. Carefully describe this cluster. Make a picture of it. Preserve the specimen for your collection.

12. Put a branch of the kind of tree upon which the caterpillars are feeding in water in a breeding cage. Select a branch which bears many leaves. Place fifteen or twenty caterpillars on this branch, in order to keep them confined, and thus be able to observe their transformations. Put fresh branches in the cage when necessary to keep the larvæ supplied with food.

13. What do the caterpillars do when full grown? Observe their actions in your breeding cage and in the field.

14. Preserve some caterpillars in alcohol, and put them in your collection near the cluster of eggs.

15. Observe and describe the making of cocoons. Note the date when the cocoons are made.

16. After you are familiar with the appearance of the cocoons, look for them out of doors, and find out where they are made.

17. Open a cocoon a few days after it is made, and describe the pupa.

18. Preserve a pupa in alcohol, and put it next to the larvæ in your collection.

19. Watch for the appearance of the adult moths, and thus determine the duration of the pupa state.

20. Preserve specimens of the cocoons and moths. First kill the moths by putting them in the killing bottle, then pin and spread them. When dry, take them from the spreading board, and put them in the collection with the other specimens illustrating the transformations of the species. Try to get both sexes of the moth; the females are larger than the males, and have narrower antennæ.

21. Make a picture of the moth.

22. Write an account of the life history of this insect.

23. Arrange the specimens of the apple-tree tent-caterpillar in your collection under a copy of the following labels:—

Order LEPIDOPTERA (Lep-i-dop'te-ra).

The Moths, the Skippers, and the Butterflies.

Family LASIOCAMPIDÆ (Las-i-o-cam'pi-dæ).

The Lasiocampids (*Las-i-o-cam'pids*).

NOTE.—There are several species of tent-caterpillars in the United States. The most common one east of the Rocky Mountains is the one figured above—the apple-tree tent-caterpillar, *Clisiocampa americana* (*Clis-i-o-cam'pa a-mer-i-ca'na*). Another species that occurs in this region is the tent-caterpillar-of-the-forest, *Clisiocampa disstria* (*C. dis'stri-a*). The larva of this species differs in having a row of spots along the middle of the back instead of a continuous, narrow line. This species will answer just as well for the work outlined above as the apple-tree tent-caterpillar.

The more common tent-caterpillars of the Pacific coast are *Clisiocampa californica* (*C. cal-i-for'ni-ca*), whose webs may be found on oaks in March and April, and *Clisiocampa constricta* (*C. con-stric'ta*), which infests fruit trees later in the season. The caterpillars of the last-named species do not make tents, although they live in colonies.

OTHER LEAF-EATING CATERPILLARS (*Field and School Work*).—There are many kinds of caterpillars that feed on the foliage of other fruit trees, any one of which will serve as a good subject for study. It would take too much space to describe many of these and to outline the method of study of them, as has been done above for the tent-caterpillars. The following brief outline will be all that is necessary for the pupils that have carefully studied several of the insects already described:—

1. Collect larvæ found feeding on the foliage of fruit trees. Try to get several specimens of each kind, and note carefully upon what they were feeding.

2. Put each kind of larva into a separate breeding cage (see pages 327 to 330 for descriptions of breeding cages), and feed each with leaves from the kind of tree on which it was found. Keep the food fresh by placing the stems in water, and renew it daily.

3. Make careful notes on the habits of the insects, and describe each stage in their development.

4. Save specimens for your collection of anything illustrating the habits of the species and specimens of each of the stages in the development of the species. Arrange these specimens in your collection, labeled as fully as you can.

5. Write an account of what you have learned.

The following are some of the more common of the orchard insects that feed on foliage:—

The yellow-necked apple-tree-worm, *Datana ministra* (*Da-ta'na mi-nis'tra*).—This caterpillar has the

FIG. 138.—The yellow-necked apple-tree-worm.

curious habit of assuming the attitude shown in Fig. 138. It feeds on forest trees as well as fruit trees. It remains throughout the winter in the pupa state. Fig. 139 represents the adult. There are several closely allied species which feed on forest trees.

FIG. 139.

The red-humped apple-worm, *Œdemasia con-*

cinna (*Œd-e-ma'si-a con-cin'na*).—The larva of the species has a coral-red head, and there is a hump of the same color on the back of the first abdominal

FIG. 140.—The red-humped apple-worm.

segment (Fig. 140). This species passes the winter in the pupa state, and the adults appear in June and July.

The measuring-worms.—There are many kinds of these. Fig. 141 represents one of them. They are called measuring-worms on account of the curious way in which they walk. The most important species that infest fruit trees are known as canker-worms. There are two species of canker-worms, which are very similar in appearance and habits. In both the adult female is wingless (Fig. 142), while the male (Fig. 143) has well-developed wings.

FIG. 141.—A measuring-worm.

FIG. 142.—Female canker-worm.

The white-marked tussock-moth, *Notolophus leucostigma* (*No-tol'o-phus leu-co-stig'ma*).—This caterpillar (Fig. 144) is

PLATE VIII.—FOREST AND ORCHARD MOTHS.

1 and 2. The Peach-tree Borer. Fig. 1, male; Fig. 2, female.

3. The Pear Midge-moth. Feeds on grape and Virginia creeper.

4. The Morning Flower Sphinx.

5. The Pear Wood-nymph, Eudamonia pyralina. Larva feeds on the leaves of Euphorbia.

6. The Grape-vine Epimenis, Pyromorpha dimidiata. Larva feeds on the leaves of grape and Virginia creeper.

7. The Maple-moth, Melanolophia imitata. The larva feeds on the leaves of oak.

8. The White-marked Tussock-moth. See page 174; also Plate XVIII. Fig. 2.

9. The Well-marked Tussock-moth.

Plate XVIII. Fig. 7, Orgyia leucostigma.

PLATE VIII.—FOREST AND ORCHARD MOTHS.

FIGURE

1, 2, and 3. The Peach-tree Borer, *Sannina exitiosa*. Fig. 1, male; Fig. 2, female; Fig. 3, cocoon with empty pupa skin projecting from it.

4. The Eight-spotted Forester, *Alypia octomaculata*. The larva feeds on grape and Virginia creeper.

5. The Morning Forester, *Alypia matuta*.

6. The Pearl Wood-nymph, *Euthisanotia unio*. The larva feeds on the leaves of Euphorbia.

7. The Grape-vine Epimenis, *Psychomorpha epimenis*. The larva feeds on the leaves of grape and Virginia creeper.

8. The Maia-moth, *Hemileuca maia*. The larva feeds on the leaves of oak.

9. The White-marked Tussock-moth, *Notolophus leucostigma*. See page 174; also Plate XVIII, Fig. 8.

10. The Well-marked Tussock-moth, *Notolophus definita*. See Plate XVIII, Fig. 7, for the larva.

Plate VIII

common on both fruit and forest trees; it is an exceedingly beautiful larva, being ornamented with bright colors. The adult female is wingless, and lays her eggs in a frothy mass on her cocoon. The male (Fig. 145) has well-developed wings.

FIG. 143.—Male canker-worm.

THE PLANT-LICE OR APHIDS (*Field and School Work*). — The plant-lice or aphids are minute insects which live by sucking the sap from the more tender portions of plants. They usually occur clustered

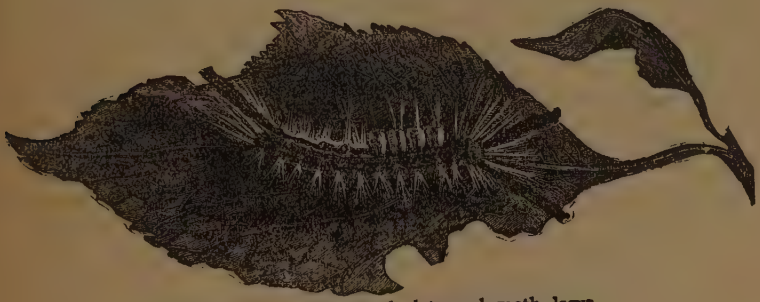


FIG. 144.—The white-marked tussock-moth, larva.

together in large numbers, and may be either winged or wingless (Fig. 146). Many kinds of aphids can be found in any orchard; among the more common

FIG. 145.

FIG. 146.—A group of aphids.

species are the green ones that are very abundant some years on the tips of branches of apple, and the dark-colored ones that cause the leaves of peach and cherry to curl, thus forming tubes within which they live.

Find a colony of aphids in a convenient place where they can be observed from day to day, take notes on their habits and structure, and finally write an account of what you have learned. The following suggestions will aid you in this study:—

1. Observe the form of the body. Usually there are two forms of individuals in a colony—one wingless, the other winged. Usually the greater number of individuals are wingless, and these never develop wings. But as aphids increase in numbers very rapidly, there is danger of the destruction of the food-plant and a consequent destruction of the colony. To avoid this danger, from time to time individuals are born that develop wings. These fly away, and start new colonies in fresh localities. The nymphs of the winged form can be recognized by their wing-pads.

2. Observe the reproduction of aphids. Both the wingless and the winged forms referred to in the preceding paragraph give birth to living young. In some species the young aphid produced in this way is inclosed in a soft shell, but usually not. The birth of the young aphids can be easily seen with a hand lens at any time during the warmer part of the year in almost any colony of aphids.

3. The two forms of aphids that are being considered now consist each of a single sex, all of the indi-

viduals being females. As these females reproduce without pairing, they are termed *agamic* (*a-gam'ic*). (The word agamic is from two Greek words, meaning without marriage.) The two forms are designated as the *wingless agamic form* and the *winged agamic form* respectively; the latter is often called the migrating form.

4. Collect specimens of the following forms of the species that you are studying, and preserve them in alcohol: — Full-grown wingless agamic females, nymphs of the wingless agamic form, winged agamic females, and nymphs of the winged agamic form.

5. Generally on the setting in of cold weather, or in some cases on the failure of nourishment, the weather being still warm, there is produced a generation including individuals of both sexes. These are known as the sexual forms. The males may be either winged or wingless, but these true females are always wingless. The sexual forms pair, and the female produces one or more eggs. It is in the egg state that the species usually pass the winter.

6. In the autumn watch for the appearance of the sexual forms and for eggs.

7. Study the agamic forms, and note if there is a pair of tubes on the back of the sixth abdominal segment. Sometimes these are represented by tubercles and sometimes they are wanting.

8. It has been generally believed that through these tubes or tubercles the sweet, transparent fluid, which is known as honey-dew, is excreted. But it has been recently discovered that the honey-dew comes from the hind opening of the alimentary

canal.* Try to observe the excretion of honey-dew.

9. Find a colony of aphids that is attended by ants, and determine why the ants are there.

INSECTS THAT PREY UPON APHIDS.

THE APHIS-LIONS (*Field and School Work*).—Look among colonies of aphids for aphis-lions. These are spindle-shaped larvæ, with very long, slender, curved jaws; one of these larvæ is represented on the lower left leaf in Fig. 147. The aphis-lions are most easily

FIG. 147.—Eggs, larva, cocoon, and adult of *Chrysopa*.

found in those colonies of aphids that live within curled leaves.

1. Remove a small branch bearing a colony of

* M. Bürgen. Der Honigtau. Jenaische Zeitschrift, Bd. xxv (1891), s. 387–428.

aphids and place it in water or wet sand in a breeding cage. Tie a wad of cotton about the branch so that aphis-lions can not easily escape from it.

2. Collect several aphis-lions and place them among the aphids, and observe their habits. If the aphids are destroyed before the aphis-lions get their growth and spin cocoons, transfer the aphis-lions to a new colony of aphids.

3. When the aphis-lions have made cocoons, transfer the cocoons to a wide-mouthed bottle covered with netting, and leave them there till the adults emerge. The adult aphis-lion is called a lace-winged-fly.

4. Search for eggs of lace-winged-flies. They can be found on the leaves of trees and bushes, attached by long, slender stalks, as shown in the figure.

5. Prepare a set of specimens illustrating the transformations of lace-winged-flies or aphis-lions, and label them as follows :—

Order NEUROPTERA (Neu-rop'te-ra).

Family CHRYSOPIDÆ (Chry-sop'i-dæ).

The Lace-winged-flies or Aphis-lions.

THE LADY-BUGS (*Field and School Work*).—The insects that are commonly called lady-bugs are small beetles which are more or less nearly hemispherical in form, and generally red or yellow with black spots, or black, with white, red, or yellow spots. Fig. 148 represents a common species. Lady-bugs, both in the adult and larval states, feed on aphids, other small insects, and the eggs of insects. The object of this

FIG. 148.

lesson is to have the pupils observe the transformations of some common species of lady-bug.

1. Collect larvæ of lady-bugs and place them in a breeding cage with a colony of aphids, putting only one kind in a cage. These larvæ can be found in the same situations as the aphis-lions (see preceding lesson), and resemble them somewhat in form. They are not so slender as the aphis-lions, and their jaws are shorter. Fig. 149 represents a common species. The breeding cage should be arranged and cared for the same as for aphis-lions.

Fig. 149.

2. Ascertain the method in which lady-bugs pass the pupa state; it is an unusual one. Fig. 150 represents a pupa.

Fig. 150.

3. Prepare a set of specimens illustrating the transformations of a species of lady-bug, and place it with your Coleoptera, labeled as follows:—

Family Coccinellidæ (Coc-ci-nel'li-dæ).

The Lady-bugs.

INSECTS INFESTING FRUIT.

The Codlin-moth (*Field and School Work*).—The most important pest of the apple is the "worm" that is frequently found feeding within the fruit near its core. This "worm" of wormy apples is the larva of a tiny moth, which is known as the codlin-moth (Fig. 151).

Fig. 151.

1. Carefully examine a number of wormy apples by cutting them to pieces, and write an account of

the injury to them. Where does the larva enter the fruit? Where is the injury chiefly done? Where does the larva emerge from the fruit?

2. In what place is it probable that the eggs of this insect are laid, judging by the observations that you have made on the habits of the larvæ?

3. Collect a large number of the larvæ by removing them from wormy apples, and place them in a tightly closed jelly-glass or other small cage. Put some pieces of apple in the cage to serve as food. Put also some small pieces of bark in the cage so that the larvæ may hide under them.

4. Describe the larva, and preserve some specimens in alcohol.

5. Observe the larvæ daily until they make their cocoons, and then describe the cocoons. Note date when the cocoons are made, so as to determine the length of time spent by the insect in its cocoon.

6. Try to find similar cocoons under loose bark on apple trees.

7. Empty cocoons of this insect are often found under loose bark that has been pierced by a woodpecker in order to feed on the insects. Preserve specimens of such pieces of bark and cocoons.

8. Scrape the loose bark from the trunk of an apple tree, and then take a piece of wrapping paper long enough to reach around the trunk and fold it so as to make a band about three inches wide, and fasten this band about the trunk. The band can be fastened in place with a tack or with a cord. Look beneath this band once a week, and collect the larvæ and pupæ that you find there, keeping a record of the number found each week.

NOTE.—At one time fruit-growers fought the codlin-moth by collecting the larvæ and pupæ in this way and destroying them. It has been found, however, that a better way is to spray the apple trees just after the blossoms fall with Paris-green-water. By this means the larvæ are poisoned before they eat their way into the young fruit.

9. Examine the cage containing cocoons daily in order to determine the date of emergence of the moths.

10. There is more than one generation of this insect each year. Determine by breeding the number of generations in your locality, and the method of passing the winter.

11. Write an account of the life history of this insect.

12. Prepare a set of specimens illustrating the transformations of this species, place them with the Lepidoptera in your collection, and label them as follows:—

Superfamily TORTRICINA (Tor-tri-ci'na).

The Tortricids (*Tor'tri-cids*).

Carpocapsa pomonella (*Car-po-cap'sa pom-o-nel'la*).

The Codlin-moth.

THE PLUM-CURCULIO (*Field and School Work*).—The plum-curculio is the insect that stings immature plums, laying eggs in them, from which hatch grubs, that cause the fruit to fall prematurely.

This insect also infests the peach, nectarine, apricot, and cherry. In the case of the cherry the infested fruit does not fall, but ripens with the larvæ in it, the larvæ being the well-known "worm" of "wormy cherries."

The study of this insect should begin early in the season, for the eggs are laid in the young fruit.

1. Search for the eggs in any of the fruits named above. Their presence can be easily determined by a peculiar mark made by the female when laying her eggs. A hole is made through the skin of the fruit, and into this hole the egg is put. The insect then makes a crescent-shaped incision partly surrounding the one containing the egg.

2. If the dot and crescent mark is found on the fruit, search should be made for the adult insects. These are most easily found early in the season, and can be readily obtained by spreading a cloth under an infested tree and jarring the tree. The adults will drop to the ground feigning death. Specimens should be pinned for your collection.

The adult is a beetle. It is about one fifth of an inch in length, and is dark brown spotted with black, yellow, and white. The wing-covers are rough, and the head is prolonged into a snout, which is bent back under the prothorax when at rest.

3. Preserve in alcohol specimens of fruit showing the dot and crescent mark. Cherries will be most available for this on account of their small size. Preserve also specimens of the larvæ.

4. Describe the way in which the larvæ injure the fruit.

5. Place infested fruit in a breeding cage on a layer of earth; determine method of passing the pupa state; preserve specimens of pupæ; and breed the adult insect, so as to determine whether the insects that you collected by jarring are really the adult of this species.

6. Write an account of the habits and appearance of this insect.

7. Label your specimens properly. The species belongs to the order Coleoptera; the family CURCULIONIDÆ (Cur-cu-li-on'i-dæ), *The Curculios* (*Cur-cu'li-os*) *or Weevils;* and the specific name of this curculio is *Conotrachelus nenuphor* (*Con-o-tra-che'lus nen'u-phor*).

THE POMACE-FLIES (*Field and School Work*).—There are several species of small flies, the larvæ of which live in decaying fruit; and as these insects are often abundant about pomace in cider-mills and wineries, they have been termed pomace-flies.

Usually the larvæ of these flies can be found in decaying fruit in any orchard during the autumn. And as they develop very rapidly, they are excellent subjects for study. In the case of one species which I studied, the complete life cycle occupied only from eleven to seventeen days.

1. Place in a breeding cage some decaying apples or other fruit in which there are maggots. There should be a layer of earth in the breeding cage, as some species of pomace-flies pass the pupa state in the ground.

2. Study the larva carefully and write a description of it. Note especially the form of the first pair of spiracles, which project near the head of the body, as these present the most obvious specific distinctions of the larvæ of the different species. The form of the caudal end of the body should be carefully studied also. The skin of these larvæ is so transparent that the larger tracheæ, or breathing tubes, can be easily seen through it with a low power of the microscope. Make a drawing representing an entire larva, and more detailed drawings representing each end of the body.

3. When the larvæ are full grown, determine where the pupa state is passed, and make a drawing of the puparium. The pupa state of most flies, including the pomace-flies, is passed within the dried skin of the larva. This dried skin, which serves the purposes of a cocoon, is termed a *puparium* (*pu-pa'-ri-um*).

4. Put some puparia in a vial in order to determine the duration of the pupa state.

5. When the adult flies emerge in your breeding cage, save some specimens for your collection, and put some living ones in a cage with decaying fruit which is not infested. If you have more than one species of pomace-flies, put the different species in different cages. Try to discover the eggs when they are laid, and to determine the duration of each stage of the insect.

6. Write an account of the pomace-flies that you have studied.

7. Prepare a set of specimens for your collection. The pomace-flies belong to the order Diptera, the family MUSCIDÆ (Mus'ci-dæ), and to the genus *Drosophila* (*Dro-soph'i-la*).

CHAPTER VII.

FOREST LIFE.

A DELIGHTFUL place for the study of insect life, especially on a hot summer day, is the margin of a forest. Here abound innumerable species, exhibiting the greatest variety of habits. And the charm of a holiday spent in the shade can be increased manifold by watching and collecting them.

The best places for the study of forest insects are the edges of woods, groves, isolated forest trees growing in open fields or by roadsides, and fringes of trees along the banks of streams. The depths of dense forests are inhabited by a much smaller number of kinds of insects than the places just named.

In the chapters on Pond Life, Brook Life, and Orchard Life detailed directions have been given for the study of the insects mentioned. But by the time the student has reached this chapter he should have become sufficiently familiar with the methods of study to be able to plan his own investigations; hence the chief object of this chapter is to point out subjects for study.

'Tis a woodland enchanted!
The great August noonlight,

Through myriad rifts slanted,
Leaf and bole thickly sprinkles
With flickering gold;
There, in warm August gloaming,
With quick, silent brightenings,
From meadow-lands roaming,
The firefly twinkles
His fitful heat-lightnings.—*Lowell.*

THE LARGER LEAF-EATING CATERPILLARS.

The Giant Silkworms.

The largest of the leaf-eating insects found on our forest trees are the giant silkworms. There are several species of these, and some of them can be found in almost any of the inhabited portions of our country.

These larvæ frequently attract attention on account of their large size, and the adults are favorites with young collectors, being the most showy of moths.

It is easy to rear these insects, beginning with either eggs, larvæ, or pupæ. The following general directions for breeding will apply to any of the species:—

Eggs of the Giant Silkworms.—The eggs of the giant silkworm moths, being of large size, are frequently found attached to leaves of the trees upon which the larvæ feed, but they are more often obtained from moths kept in confinement. When a female moth is captured it is usually only necessary to place her in a breeding cage, and keep her alive for a few days, in order to obtain fertile eggs. The females of this family of moths can be recognized by

the fact that the antennæ are not so large as are the antennæ of the males. In case a female moth is bred from a cocoon, it is necessary that she should be allowed to mate with a male in order that her eggs be fertilized. If there be no males in the cage with her, males can usually be obtained by leaving the cage near an open window for a day or two. Frequently under such conditions males will come to the cage in large numbers. Having obtained eggs, it is necessary to ascertain the food plant of the larva; the more common food plants of each of the species is given below.

Larvæ of the Giant Silkworms.—These larvæ can be found throughout the summer months, but they are more frequently observed in the latter part of the season, when they are nearly or quite full grown. The collection of them is greatly facilitated by searching beneath the trees on which they live for the pellets of excrement which drop to the ground from where they are feeding. In collecting them, note carefully their food plant.

Cocoons of the Giant Silkworms.—The pupa state of the giant silk-worms is passed within dense silken cocoons, which have suggested their popular name. All of our species pass the winter in this state, and several of them fasten their cocoons to the branches of trees; consequently it is during the winter months, while the trees are bare, that the cocoons are most often collected. Cocoons which are collected during the winter should be stored in a cool place till spring, so that the adults shall not emerge before it is possible to find food for the larvæ that will hatch from their eggs. Even when it is not desired to breed a

PLATE IX. A FOREST AISLE.

second generation, it is undesirable to keep the cocoons during the winter months in a warm, dry room, for there is apt to be insufficient moisture in the air of such a room for the perfect development of the insects.

Classification of the Giant Silkworms.—The giant silkworms, being the larvæ of moths, belong to the order Lepidoptera. These moths constitute the family SATURNIIDÆ (Sat-ur-ni'i-dæ). The scientific name of each of the species mentioned below is given after the popular name. The following are the more common North American species:—

THE IO-MOTH, *Automeris io* (*Au-tom'e-ris i'o*).—This is the most common of the smaller species of the family. The female is represented by Fig. 152. In this sex the ground color of the fore wings is

FIG. 152.—The io-moth.

purplish red. The male differs greatly in appearance, being somewhat smaller and of a deep yellow color, but it can be easily recognized by its general resemblance to the female in other respects.

The larva (Fig. 153) is one that the student should learn to recognize in order that he may avoid handling it, for it is armed with spines the prick of which is venomous. It is green, with a broad brown or reddish stripe, edged below with white on each side of the abdomen; the spines are tipped with black. It feeds on the leaves of apple, cherry, willow, elm, currant, and many other plants. The cocoon is thin; it is usually surrounded by leaves, and made near the ground. The adults sometimes emerge in the autumn, but usually not till spring.

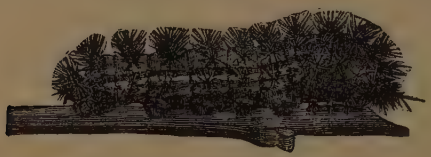


FIG. 153.—Larva of the io-moth.

THE POLYPHEMUS-MOTH, *Telea polyphemus* (*Te'le-a pol-y-phe'mus*).—This is a yellowish or brownish moth, with a windowlike spot in each wing. There is a gray band on the front margin of the fore wings, and near the outer margin of both pairs of wings there is a dusky band, edged without with pink; the fore wings are crossed by a broken dusty or reddish line near the base, edged within with white or pink. The transparent spot on each wing is divided by a vein and encircled by yellow and black rings. The wings expand from five to six inches.

The larva (Fig. 154) feeds on oak, basswood, butternut, elm, maple, apple, plum, and other trees. When full grown, it measures three inches or more in length. It is of a light green color, with an oblique yellow line on each side of each abdominal segment except the first and last; the last segment is bordered

by a purplish brown V-shaped mark. The tubercles on the body are small, of an orange color, with me-

FIG. 154.—Larva of the Polyphemus-moth.

tallic reflections. The cocoon (Fig. 155) is dense and usually inclosed in a leaf. Sometimes it is fastened to a twig, but ordinarily it falls to the ground with the leaves in the autumn. Observe and

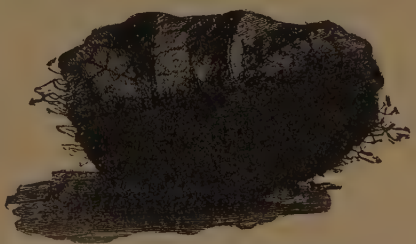


FIG. 155.—Cocoon of the Polyphemus-moth.

describe the method of exit of the adult from the cocoon.

THE LUNA-MOTH, *Tropæa luna* (*Tro-pæ'a lu'na*).—This is the most beautiful of the giant silkworm moths. Its wings are of a delicate light green color, with a purple-brown band on the front edge of the

FIG. 156.—The luna-moth.

fore wings. It can be easily recognized by Fig. 156.

The larva feeds on the leaves of walnut, hickory,

and other forest trees. It measures when full grown about three inches in length. It is pale bluish green, with a pearl-colored head. It has a pale yellow stripe along each side of the body, and a transverse yellow line on the back between each two abdominal segments. The cocoon resembles that of the preceding species in form, but is very thin, containing but little silk. It is found on the surface of the ground beneath the trees on which the larvæ feed.

THE PROMETHEA-MOTH, *Callosamia promethea* (*Cal-lo-sa'mi-a pro-me'the-a*).—The female moth of this species can be recognized by Fig. 157. The male differs

FIG. 157.—The Promethea-moth, female.

so greatly from the female that it is liable to be mistaken for a distinct species. It is blackish, with the transverse lines very faint, and with the spot near the center of each wing wanting or very faintly indi-

cated. The fore wings also differ markedly in shape from those of the female, the apex of each being much more distinctly sickle-shaped. We have obtained forty males of this species in a single afternoon by placing a cage containing living females near an open window. They fly most in the latter part of the afternoon.

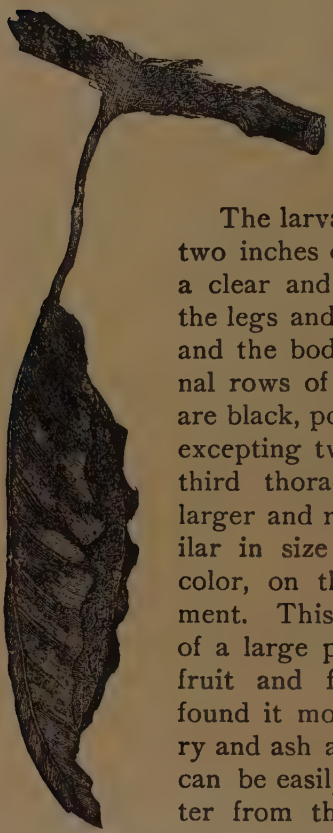


FIG. 158.—Cocoon of the Prometheamoth.

The larva when full-grown measures two inches or more in length. It is of a clear and pale bluish green color; the legs and oval shield are yellowish, and the body is armed with longitudinal rows of tubercles. The tubercles are black, polished, wartlike elevations, excepting two each on the second and third thoracic segments, which are larger and rich coral-red, and one similar in size to these, but of a yellow color, on the eighth abdominal segment. This larva feeds on the leaves of a large proportion of our common fruit and forest trees, but we have found it most frequently on wild cherry and ash and on lilac. The cocoons can be easily collected during the winter from these trees. The cocoon is greatly elongated, and is inclosed in a leaf, the petiole of which is securely fastened to the branch by a band of silk extending from the cocoon (Fig. 158). At the

upper end of the cocoon there is a conical, valve-like arrangement, which allows the adult to emerge without the necessity of making a hole through the cocoon. Cut one of your cocoons in two crosswise so as to see this valve.

THE CECROPIA-MOTH, *Samia cecropia* (*Sa'mi-a ce-cro'pi-a*).—This is the largest of our giant silkworm

FIG. 159.—The Cecropia-moth.

moths, the wings expanding from five to six inches and a half. It can be recognized by Fig. 159. The larva is known to feed on at least fifty species of

plants, including apple, plum, and the more common forest trees. When full grown it measures from three to four inches in length, and is dull bluish green in color. The body is armed with six rows of tubercles, extending nearly its entire length, and there is an additional short row on each side of the ventral aspect of the first five segments following the head. The tubercles on the second and third thoracic segments are larger than the others, and are coral red. The other dorsal tubercles are yellow, excepting those of the first thoracic and last abdominal segments, which, with the lateral tubercles, are blue; all are armed with black bristles. The cocoon (Fig.

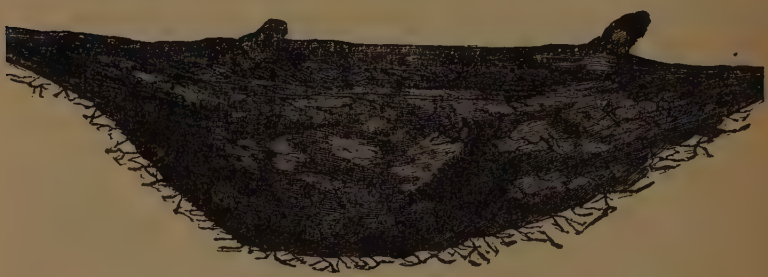


FIG. 160.—Cocoon of the Cecropia-moth.

160) is securely fastened to a branch of the food plant, where it is easily found during the winter months.

THE CEANOTHUS SILKWORM, *Samia californica.*—The Cecropia-moth is not found on the Pacific coast, but its place is taken by a closely allied species similar in size and markings, but differing in having the ground color of the wings reddish or dusky brown. The larva feeds on *Ceanothus;* the cocoon resembles

Plate X

Plate X.—Some Forest Moths.

FIGURE

1. The Imperial-moth, *Basilona imperialis*. The larva feeds on hickory, butternut, and other forest trees. See page 197.
2. The Io-moth, *Automeris io*. Male. See page 189 for figure of the female.
3. The Rosy Dryocampa, *Dryocampa rubicunda*. The larva is the green-striped maple-worm.
4. The Crinkled Flannel-moth, *Megalopyge crispata*. The larva feeds on oak, elm, apple, and raspberry.

that of the Cecropia-moth, except that the ends are usually free from the branch to which the cocoon is attached.

THE ROYAL-MOTHS.

The royal-moths constitute a family, the CITHERONIIDÆ (Cith-e-ro-ni'i-dæ), which is closely allied to the giant silkworms. The species are of medium or large size, and some of them are among the more common forest insects. The larvæ are armed with horns or spines, of which those on the second thoracic segment, and sometimes also those on the third, are long and curved. These caterpillars eat the leaves of forest trees, and go into the ground to transform, which they do without making cocoons. The rings of the pupa bear little notched ridges, the teeth of which, together with some strong prickles at the hind end of the body, assist it in forcing its way upward out of the earth. The following are the more common species:—

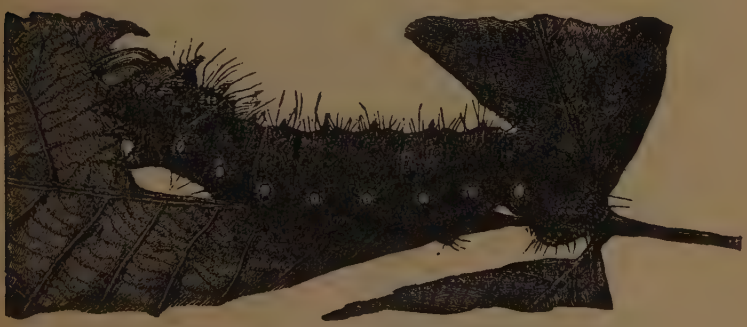


FIG. 161.—Larva of the imperial-moth.

THE IMPERIAL-MOTH, *Basilona imperialis* (*Bas-i-lo'na im-pe-ri-a'lis*).—The full-grown larva of this species

FIG. 162.—The regal-moth.

(Fig. 161) measures from three to four inches in length. It feeds on hickory, butternut, and other forest trees. The moth expands from four to five inches and a half. It is sulphur-yellow, banded and speckled with purplish brown.

THE REGAL-MOTH, *Citheronia regalis* (*Cith-e-ro'ni-a re-ga'lis*).—This is the largest and most magnificent of the royal-moths (Fig. 162). The fore wings are olive-colored, spotted with yellow, and with a more or less distinctly marked band outside the middle olive. The wings expand from four to six inches.

The larva, when full grown, measures from four to five inches in length, and can be recognized by the very long, spiny horns with which it is armed. Those of the mesothorax and metathorax are much longer than the others; of these, there are four on each segment; the intermediate ones measure about three fifths of an inch in length. The larva feeds on hickory, walnut, and various other trees.

THE ANISOTA OAK-WORMS.—There are several smaller royal-moths belonging to the genus *Anisota* (*An-i-so'ta*), the larvæ of which feed on oak.

FIG. 163.—*Anisota*, male.

FIG. 164.—*Anisota*, female.

These larvæ are more or less striped and armed with spines. In the adult state the sexes differ greatly in

appearance. The male and female of a common species are represented by Figs. 163 and 164.

THE LARGER NEST-BUILDING CATERPILLARS.

Many species of caterpillars make nests within which they live. The greater number of these belong to the group described below as leaf-rollers—a group composed chiefly of very small species. A few of the larger caterpillars also make nests. The more common species of these are the following:—

THE TENT-CATERPILLARS.—See page 172 for a reference to these.

THE FALL WEB-WORM, *Hyphantria cunea* (*Hy-phan'tri-a cu'ne-a*).—A very common sight in autumn in all parts of our country is large, ugly webs inclosing branches of fruit or forest trees. These webs are especially common on apple and on ash. Each web is the residence of a colony of larvæ which have hatched from a cluster of eggs laid on a leaf by a snow-white moth. There is a variety of this moth in which the fore wings are thickly studded with dark brown specks. Every gradation exists between this form and those that are spotless. The species winters in the pupa state, and the moths emerge during May or June. The webs made by this insect should not be confounded with those made by the apple-tree tent-caterpillar. The webs of the fall web-worm are made in the autumn, and are much lighter in texture, being extended over all of the leaves fed upon by the colony.

THE SCALLOP-SHELL MOTH, *Calocalpa undulata* (*Cal-o-cal'pa un-du-la'ta*).—This is a pretty moth, with its yellow wings crossed by so many fine, zigzag,

dark brown lines that it is hard to tell which of the two is the ground color (Fig. 165). It lays its eggs in a cluster on a leaf near the tip of a twig of cherry, usually wild cherry. The larvæ make a snug nest by fastening together the leaves at the end of the twig, and within this nest (Fig. 166) they live, adding new leaves to the outside as more food is needed. The leaves die and become brown, and thus render the nest conspicuous. The larvæ are black above, with four white stripes, and flesh-colored below. When full grown they descend to the ground to transform, and pass the winter in the pupa state.

FIG. 165.—The scallop-shell moth.

FIG. 166.—Nest of larvæ of the scallop-shell moth, and eggs of moth enlarged.

THE MOCHA-STONE MOTHS, *Ichthyura* (*Ich-thy-u'ra*).—There often occur on poplar and willow nests of the form shown in Fig. 167. Each of these nests

contains a colony of larvæ—the young of a moth of the genus Ichthyura, of which there are several spe-

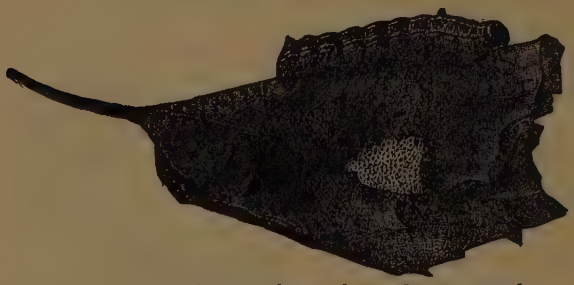


FIG. 167.—Eggs, larva, and nest of a mocha-stone moth.

cies in this country. The moths are brownish gray, with the fore wings crossed by irregular whitish lines (Fig. 168). It was these peculiar markings, resembling somewhat those of a moss-agate, that suggested the popular name given above. In the case of our most common species, the nests are found in midsummer or later. The larvæ, when young, feed within the nest, but when they become large they leave the nest at night to feed on other leaves. The cocoons are made under leaves or other rubbish on the ground, and the adults do not emerge until the following summer. These insects can be easily bred by placing a nest in a breeding cage and putting fresh branches of the food plant next to the nest as often as necessary.

FIG. 168.—A mocha-stone moth.

THE SILVER-SPOTTED SKIPPER, *Epargyreus tityrus* (*Ep-ar-gy're-us tit'y-rus*).—If one will lie on his back in

late July or in September under the low hanging branches of some locust tree, and look so that the leaves are clearly outlined against the sky, he may see that the fernlike regularity of some of the compound leaves is interrupted, several of the leaflets being fastened together with silk so as to make a little tube, which serves as a home for the builder. These tubes are made in various ways; sometimes the tips of several pairs of opposite leaflets are brought together below the leaf-stalk and fastened with silk, and the overlapping edges of the leaflets on each side fastened in the same way; thus is formed a roomy chamber, within which the architect lives.

The remains of such a nest is represented in Fig. 169. When this specimen was collected late one

FIG. 169.—Nest of a larva of the silver-spotted skipper.

afternoon, the leaflets were all present on the stem; but when I went to photograph it the next morning I found that the caterpillar during the night, having nothing else to feed upon, had eaten the leaflets at both ends of the nest.

These nests are made by the larva of the silver-spotted skipper, a butterflylike insect which flies from

flower to flower with a skipping motion (see page 81 for the characteristics of the skippers). This skipper is dark chocolate-brown, with a row of yellow spots extending across the fore wing, and with a large, silvery white spot on the lower side of the hind wing. The larva is a curious creature, with a large head, a slender neck, and a spindle-shaped body (Fig. 170), and will serve as a type of the family HESPERIIDÆ (Hespe-ri'i-dæ), which includes our common skippers; for the larvæ of this family can be recognized by this peculiar form, and most of them live concealed in a folded leaf or in a nest made of several leaves fastened together.

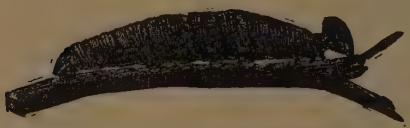


FIG. 170.—Larva of the silver-spotted skipper.

THE BAG-WORMS, family PSYCHIDÆ (Psy'chi-dæ). —The bag-worms are those caterpillars that have the curious habit of building each for itself a silken sac covered with little twigs within which it lives (Figs. 171 and 172). When the caterpillar wishes to move from one place to another, it pushes forth the front end of its body and creeps along, carrying its house with it. It is said that the species that inhabit Ceylon are believed by the natives to be composed of individuals who, in a previous incarnation, were human beings and stole kindling-wood, and who now atone for the theft by repeating the act as an insect.

FIG. 171.

Plate XI.—UNDER-WING MOTHS.

The under-wing moths are found resting on the trunks of forest trees; when at rest, the bright-colored hind wings are covered by the fore wings, and the insects are well-protected by their resemblance in color to the bark of the trees.

FIGURE

1. *Catocala concumbens.*
2. *Catocala gracilis.*
3. *Catocala amica.*
4. *Catocala ultronia.*
5. *Catocala relicta.*

Plate XI

When a bag-worm is fully grown, it fastens its sac to a twig and changes to a pupa within it. And here the females remain until death, leaving their eggs within their sacs. These females are grublike creatures without wings. But the male pupa works his way out from the lower end of his sac, and changes to a winged moth. Fig. 172 represents the

FIG. 172.

FIG. 173.

FIG. 174.

sac of a male with the empty pupa skin projecting from the lower end, and Fig. 173 the fully developed male. These figures are of one of our smaller species. Fig. 174 represents the male of one of the larger species.

OTHER LARGER LEAF-EATING CATERPILLARS.

In addition to the species mentioned above, there are very many of the larger caterpillars that infest the foliage of forest trees. Any one of these may be taken as a subject for study, and the work carried on in the manner outlined for the study of similar orchard insects. See page 172.

THE SMALLER LEAF-EATING CATERPILLARS.

There is an immense number of small caterpillars that infest the foliage of forest trees. Of this number, the majority of those that would attract the attention

of the young student represent two groups—the leaf-rollers and the leaf-miners.

THE LEAF-ROLLERS.

If the pupil will examine the leaves of almost any forest tree during the summer or autumn he will find that some of them are rolled in such a way as to form a nest, within which one or more larvæ live or have lived. These nests vary greatly in form; sometimes a single leaf, or even only a part of a leaf, is rolled; in other cases the nest is formed by fastening together several leaves. In most cases the building of the nest is the work of a single larva, but in very many instances several larvæ work together to build a common nest. It should be said, however, that each of the leaf-rolling species builds a nest of a particular form, and each of these species infests a certain kind or kinds of trees. Hence, when a student has carefully studied the life history of a leaf-roller, he will be able, as a rule, to recognize the work of this species by a study of the nest alone.

FIG. 175.

In making its nest the leaf-roller fastens the folds of its nest in the desired position by means of little bands of silk. Several of these bands are shown in Fig. 175, and in Fig. 176 are represented several types of nests made of rolled leaves.

The breeding of leaf-rollers is somewhat more

difficult than the breeding of those leaf-eating species that do not make nests; the changing of the latter from a wilted branch to a fresh one is accomplished without difficulty, but a similar process in the case of a leaf-roller implies the building of a new nest by the insect. For this reason it is best to leave the nests on the trees till the larvæ are nearly full-grown, and then to cut the branch bearing the nest and place it in water or damp sand in a breeding cage. This implies the keeping of a close watch of the insects while on the trees, lest they mature and escape. It is well, when comparatively few specimens are found, to inclose the nest while it is left on the tree in a bag of Swiss muslin. Some leaf-miners pass the pupa state within their nest; but as others leave the nests and enter the ground to transform, it is best to have a layer of earth in the breeding cage.

FIG. 176.

The greater number of the leaf-rolling caterpillars belong to the superfamily TORTRICINA (Tor-tri-ci'na), or *Tortricids* (*Tor'tri-cids*); but there are members of several other families of moths that have similar habits.

THE LEAF-MINERS.

There are many leaf-eating caterpillars that are so minute that they can live within the substance of a leaf, the space between the two skins of the leaf being sufficiently large to afford them room for a dwelling and pasture. The larvæ that live in this way are called leaf-miners.

During the late summer and autumn there can be found on almost any shrub or tree leaves that are more or less discolored by white or grayish blotches or by long twisted lines that reveal the abiding-places of leaf-miners. Surely Mr. Lowell must have had these in mind when he wrote:—

> And there's never a blade nor a leaf too mean
> To be some happy creature's palace.

Not only are very many kinds of plants infested by these larvæ, but the mines in the leaves differ greatly in form and in their position in the leaf. These differences in food plant and in the shape and position of the mines do not indicate that these larvæ are inconstant in their habits. In fact, the opposite is the case. Each species of leaf-miner infests a particular species of plant, or, at the most, several closely allied plants. And each species makes a mine of definite shape, although some species exhibit different habits in the different stages of their growth. So constant are these creatures in their habits that in most cases an expert can determine the species of leaf-miner that made a mine by merely examining the infested leaf.

The various kinds of mines can be classed under a

few distinct types. The long, narrow, and more or less winding mines are described as *linear mines.* Some of these are very narrow at their beginning and gradually enlarge, resembling in outline a serpent; frequently the larger end is terminated by a blotchlike enlargement, suggesting a head. Such mines are termed *serpentine mines.* The leaves of the wild columbine are often marked by serpentine mines (Fig. 177). Other mines that start from a narrow beginning enlarge more rapidly and extend in a more or less regular curve; these are *trumpet mines.*

FIG. 177.—Leaf with serpentine mines.

The breeding of leaf-miners is attended by the same difficulties as the breeding of leaf-rollers mentioned above. But with a little care mines can be selected in which the larvæ are so nearly full grown that they will complete their transformations if the branch bearing the mined leaves be placed in water or damp sand in a breeding cage. When the adult insects are reared, great care will be necessary in mounting them on account of their minute size. See page 298 for directions for mounting small insects.

A very instructive collection can be made by pressing mined leaves, and mounting them as botanical specimens are mounted. Each specimen should

be carefully labeled with the name of the plant and the date of collecting the specimen.

There are certain flies and beetles the larvæ of which are leaf-miners, but the great majority of the insects that live in this way are larvæ of minute moths, which belong to the superfamily TINEINA (Tin-e-i'na); these are commonly called *Tineids* (*Tin'-e-ids*).

GALLS AND GALL-INSECTS.

There occur on the leaves, stems, or roots of very many species of plants abnormal growths caused by insects; these are termed galls. Among the more familiar examples of galls are the various kinds of

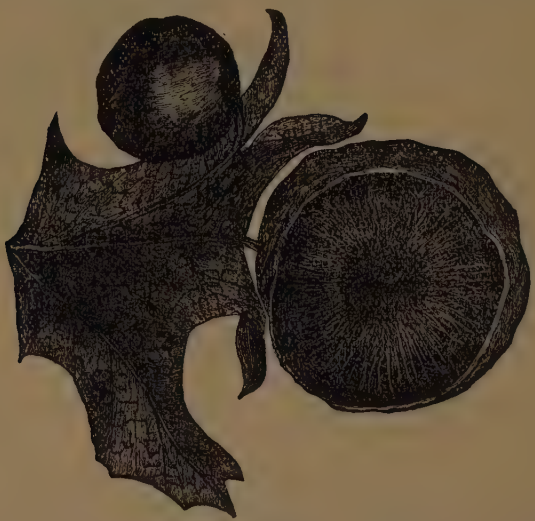


FIG. 178.—An oak leaf bearing oak-apples. The larger one is represented cut open.

oak-apples, of which a common one is illustrated by Fig. 178.

In the center of an oak apple there is a little cell, within which a larva lives till it gets its growth. This larva is hatched from an egg laid in the tissue of the leaf by a small, four-winged insect, called a gall-fly. When the young larva began to feed on the leaf, the leaf began to grow around it in a wonderful way; so that very soon the larva was surrounded by a large ball of plant growth, which served as a home and furnished food for the larva.

Why the plant grew in this way no one knows. As a rule, when a leaf-eating larva feeds on the tissue of a leaf there is no extra growth; but when the larva of a gall-fly begins to feed, an abnormal growth of the plant commences. More than this, this growth is of a definite form which is different for the different species of gall-flies. Hence, when an entomologist who has studied these insects sees a familiar gall, he knows at once what species of insect produced it. It is natural to suppose that the larva excretes a poison, which acts on the plant in such a way as to produce this remarkable result. There are certain other gall-producing insects which belong to a different order than those that produce the oak-apples, the galls of which begin to grow before the larvæ hatch. In these cases it is supposed that a drop of poison is deposited with the egg by the parent insect.

Many species of gall-flies undergo their transformations within their galls, while in other species the full-grown larva leaves the gall and enters the ground to transform.

The gall represented by Fig. 178 is produced by a single larva. But certain species of gall-flies lay many eggs together, and there results the growth of

a compound gall containing many cells, in each of which a larva gets its growth. The mossy-rose-gall, which occurs on the stem of the sweetbrier (Fig. 179), is a familiar example of a many-celled gall.

FIG. 179.—The mossy-rose-gall.

In the two kinds of galls figured here the larva lives in a closed cell which has no opening until one is made by the full-grown larva for his escape. Most galls of this kind are made by insects of the family CYNIPIDÆ (Cy-nip'i-dæ) of the order Hymenoptera. To this family the name gall-flies is restricted, although many other insects produce galls. Fig. 180 represents an adult gall-fly greatly enlarged.

The largest galls that occur on forest trees are produced by gall-flies, but there are other kinds of

galls which are much more abundant than those of the gall-flies; these are the galls made by plant-lice and by mites. The galls produced by plant-lice, and also those produced by mites, differ from the galls of the gall-flies in that each gall has an open mouth.

Fig. 180.—A gall-fly.

The conical galls which are so common on the leaves of witch-hazel (Fig. 181) are good illustrations of this type of gall. These galls project from the upper side of the leaf, but each has an opening on the lower side of the leaf. The plant-louse that produces this gall is an agamic female (see page 177); when this female is mature, she gives birth to numerous young, which escape from the mouth of the gall, scatter over the leaf, and each in turn produces a gall.

Fig. 181.

In most localities there are so many kinds of galls that it would be unwise for a student to attempt to study them all. A better plan is to select some one species or genus of trees and to study the galls made on these trees by one family of insects. Thus, if oaks occur in the locality, a good subject is the oak galls

made by gall-flies (family *Cynipidæ*). The student should learn the different species of oaks that grow in the locality, and should always label the galls collected with the name of the particular species of oak on which they were found. The particular time of the year in which the galls are developed should be determined, and an effort should be made to breed the adult gall-flies. Many species of gall-flies undergo their transformations within their galls, while in other species the full-grown larva leaves the gall and enters the earth to transform. In the former case the adults are most surely obtained by leaving the galls on the trees and inclosing each in a little bag of Swiss muslin. And in the latter case care must be taken not to collect the galls before they are mature, else they will wither and the contained larvæ perish. In breeding species that pass the winter in their galls, the galls should be left out of doors till spring to prevent the galls becoming too dry and hard.*

In the study of galls made by plant-lice, select some common species of gall, so that specimens can be cut open and examined at frequent intervals. Note carefully by this method what goes on within the galls, and observe the spreading of the young from the galls and the formation of new galls.

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* For a thorough study of this subject, see the following :—Alternating Generations: A Biological Study of Oak Galls and Gall-flies. By Hermann Adler. Translated and edited by Charles R. Straton. Published by Macmillan & Co. Price, $3.25.

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PLATE XII. LONG-HORNED BEETLES.

INSECTS INFESTING THE TRUNKS AND BRANCHES OF TREES.

The insects that live within the trunks and branches of trees are called borers. There are very many species of these, and representatives of several of the orders of insects, as well as of many different families, are found among them.

In the study of these insects larvæ should be collected from the infested trees from time to time and preserved in alcohol; when the insects have transformed to pupæ, these can be transferred to breeding cages and the adults reared.

If the infested wood is dead, a piece of it containing the borers can be placed in a breeding cage at once, as soon as the larvæ are found, and the insects bred in this way.

Among the more common borers are the larvæ of the long-horned beetles, which constitute the family CERAMBYCIDÆ (Cer-am-byc'i-dæ). The larvæ are footless grubs of the form shown in Fig. 182. The pupa state in some species is passed within the burrows made by the larvæ; in other species the larva makes a little ring of chips around itself between the bark and the wood, and changes to a pupa within this rude cocoon. Several examples of beetles of this family are represented on Plate XII.*

FIG. 182.

* EXPLANATION TO PLATE XII.—1. The ribbed pine-borer, *Rhagium lineatum;* 2. The two-spotted Oberea, *Oberea bimaculata*, a borer in blackberry and raspberry; 3. The sawyer, *Monohamus confusor*, a borer in pine and fir; 4. The broad-necked Prionus, *Prionus laticollis*, a borer in the roots of grape, apple, poplar, and other trees; 5. The beautiful maple-borer, *Plaginotus speciosus.*

If the bark be pulled from dead branches or trunks of trees, the inner layer and the sap-wood will be found to be ornamented in many cases with burrows of more or less regular form. These smoothly cut figures are the mines of the engraver-beetles. Many kinds of these engravings can be found, each charac-

FIG. 183.

teristic of a particular kind of engraver-beetle. A common pattern is shown in Fig. 183. The beetles that do this work are mostly of cylindrical form and of small size; many species are almost microscopic, and the larger ones rarely exceed a quarter of an inch in length. They are usually brown, sometimes black, and with many the hind end of the body is very blunt, as if cut off. These beetles belong to the family SCOLYTIDÆ (Sco-lyt'i-dæ).

FIG. 184.—A horn-tail.

The insects known as horn-tails are often found

on the trunks of forest trees, in the wood of which the larvæ bore. Fig. 184 represents an adult horn-tail. In this family the female has a long ovipositor, with which she makes slender holes in the trunks of trees for the reception of her eggs. The horn-tails belong to the family SIRICIDÆ (Si-ric'i-dæ) of the order Hymenoptera.

Among the more striking in appearance of the insects found on forest trees are certain ichneumon-flies that are parasitic on the larvæ of the horn-tails. These ichneumon-flies bore holes into the trees infested by the horn-tails, and lay their eggs into the burrows of the latter. The larvæ of the ichneumon-flies fasten themselves to the horn-tail larvæ, and destroy them by sucking their blood. Fig. 185 represents one of these ichneumon-flies in the act of laying an egg. These insects belong to the family ICHNEUMONIDÆ (Ich-neu-mon'i-dæ) of the order Hymenoptera.

FIG. 185.—The horn-tail parasite laying an egg.

MISCELLANEOUS FOREST INSECTS.

The Cicadas.

The shrill Cicadas, people of the pine
Making their summer lives one ceaseless song.—*Byron.*

Our more common species of cicadas are large insects, but as the nymphs live in the ground, and the adults spend most of their time high up among the branches of trees, they would attract comparatively little attention were it not for their songs. The student of forest insects, however, is soon made aware of the presence of cicadas if he collects at midday during the period of flight of these insects. Their song is a high, sharp trill, that far exceeds in volume the song of any other insect that sings in the daytime.

FIG. 186.

One of our most common species is the dog-day-harvest-fly, *Cicada tibicen* (*Ci-ca'da ti-bi'cen*). This insect (Fig. 186) is black and green in color and more or less powdered beneath. It is found every year in the localities in which it occurs, although it requires two years for an individual to attain its development.

The species of cicada that attracts most attention is the periodical cicada, *Cicada septendecim* (C. *septen'de-cim*). This species is often called the seventeen-year locust; but as it is not a locust, this name should

not be used. This species is not quite so large as the dog-day-harvest-fly, and is black and brick-red in color. It is remarkable on account of the slowness of its growth, the nymphs requiring seventeen years for their development in the North and thirteen years in the South. As all of the members of one generation reach the adult state at about the same time, the species appears in immense swarms which attract general attention. In many localities several broods coexist; this explains the fact that in such places these insects appear several times during a single period of seventeen or thirteen years. The adult female lays her egg in slits which she makes in the twigs of trees. The eggs hatch in about six weeks. The young nymphs drop to the ground and bury themselves in the earth, where they live by sucking the juices from the roots of trees. When full-grown, seventeen or thirteen years later, they crawl up to the surface of the ground and undergo their last molt on the trunks of trees. The last nymph skin is left clinging to the bark where the transformation occurred, and soon afterward the songs of the insects are heard.

The student should collect nymph skins, adults, and twigs in which the eggs have been laid.

The cicadas constitute the family CICADIDÆ (Ci-cad'i-dæ) of the order Hemiptera.

THE TREE-HOPPERS, OR BROWNIE-BUGS.

The tree-hoppers are so called because they live upon trees, bushes, and vines, and can jump with great agility. Many of them are grotesque in appearance, having great humps on their backs; and in

all the prothorax is prolonged backward like a roof over the body (Fig. 187). A common species bears a pair of hornlike projections, which have given it the name of the buffalo tree-hopper (Fig. 188); and another common species (Fig. 189) excretes honey-dew, and is attended by ants. If the young entomologist wishes to laugh, let him look at the faces of tree-hoppers through a lens. A front view of several of these insect-Brownies is given in Fig. 190. Their eyes have a keen, droll look, and the line that separates the head from the prothorax gives them the appearance of wearing glasses. In some cases the prothorax is elevated above the head, so that it looks

FIG. 187.

FIG. 188.

FIG. 189.

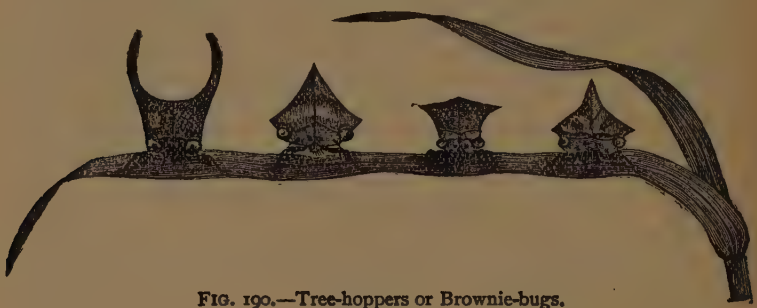

FIG. 190.—Tree-hoppers or Brownie-bugs.

like a peaked nightcap; in others it is shaped like a Tam-o'-shanter; while others have prominent horns.

The tree-hoppers feed upon plants, but they seldom appear in sufficient numbers to do much damage. They constitute the family MEMBRACIDÆ (Mem-brac'-i-dæ) of the order Hemiptera.

PLATE XIII. ROADSIDE BUTTERFLIES.

CHAPTER VIII.

ROADSIDE LIFE.

FOR the careful collector of insects, a country roadside is always a fruitful field. Here live all the insects described in the preceding chapters, for there are roadside ponds, brooks, orchards, and forests, as well as meadows. But this chapter is devoted to a few of the more prominent insects that live in grassy places, or on common roadside weeds and shrubs, or that lurk under stones, or that mine in roadside paths and cliffs.

As in the preceding chapter, the principal object here is to point out subjects for study. The students that have carefully carried out the work indicated in

earlier chapters will not need, in most cases, detailed directions for the study of these subjects; in a few cases special directions are given.

Balloons from the thistles
Tell summer's disasters,
The butterflies yellow,
As caught in an eddy
Of air's silent ocean,
Sink, waver, and steady
O'er goat's-beard and asters,
Like souls of dead flowers,
With aimless emotion
Still lingering unready
To leave their old bowers.—*Lowell.*

SPIDERS.

Any one that loves the study of insect life is sure to be interested in the habits of spiders, although these creatures are not true insects; and there is no better place for observing them than by roadsides. There are very many kinds of spiders, representing many different families, but only a few of the more prominent ones can be mentioned here.

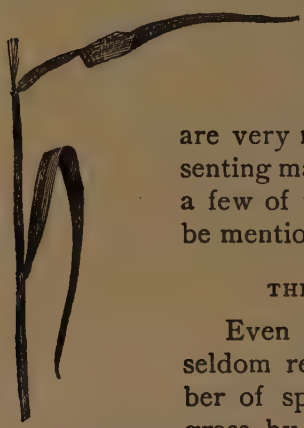

FIG. 191.—Folded leaf of grass with egg-sac of spider.

THE FUNNEL-WEB WEAVERS.

Even the most careful observers seldom realize what an immense number of spider-webs are spun upon the grass by roadsides. But occasionally these webs are made visible in the early morning by the dew which has con-

densed upon them. At such times we may see the grass covered by an almost continuous carpet of silk.

The greater number of the webs seen at such times are of the form which we term funnel-webs. They consist of a concave sheet of silk, with a funnel-shaped tube at one side, and numerous lines extending in all directions to the supporting spears of grass (Fig. 192). The tube serves as a hiding place

FIG. 192.—Web of the grass-spider.

for the owner of the web; from this retreat the spider runs out on the upper surface of the web to seize any insect that alights upon it. The tube opens below, near the roots of the grass, so that the

spider can escape from it if a too formidable insect comes upon the web.

The most common species of funnel-web weaver is the grass-spider, *Agalena nævia* (*Ag-a-le'na næ'vi-a*); this abounds in all parts of the United States.

THE ORB-WEAVERS.

Those spiders that build nets which consist of a framework of radiating lines upon which is fastened a thread in a spiral manner (Fig. 193) are called the orb-weavers. There are many species of these, each differing somewhat in habits, but the more general features of their webs are quite similar.

FIG. 193.—Partially completed web of an orb-weaver.

No more interesting subject for study can be found than the methods of work of these spiders; and we will not deprive the student of the pleasure of finding out for himself how they build their webs by describing the process in detail. We will, however, help him a little by calling attention to a few points.

Find a completed web, and examine carefully the silk of which it is composed. With a small stick

touch one of the turns of the spiral line, and observe the result when you attempt to take the stick away. In a similar manner touch one of the radiating lines, and also some of the lines that form the irregular outer framework of the web. You will discover that there are two kinds of silk in the web of an orb-weaver, which differ in two important characteristics; note what these are, and determine to what extent each kind is used. What advantages are gained by the use of each of these kinds of silk?

FIG. 194.— A dewy morning.

If you have the use of a microscope, press a glass slip against a web so that a section of it shall adhere to it, and examine this section with a microscope. Make a sketch showing the difference in appearance of the two kinds of silk.

Find a partially completed web and observe that a temporary, spiral stay-line (Fig. 193, *a*, *a*) is used in the construction of the web before the appli-

cation of the permanent spiral line (Fig. 193, *b*, *b*). How do these two lines differ? What becomes of the first line?

Throw an insect into a completed web and make notes on the way in which the spider captures and destroys its prey. If the web be that of one of the larger orb-weavers, a large insect, as a locust or grasshopper, can be used.

Study different species of orb-weavers, and note differences in the structure of their webs and in the position of the spiders while waiting for their prey.

Write an account of the habits of an orb-weaver.

On dewy mornings the webs of the orb-weavers are often heavily loaded with dew, so that adjacent turns of the spiral thread adhere together. Fig. 194 represents such a web—one that the writer saw from his window while at work on this book.

BALLOONING SPIDERS.

There are certain spiders that make long journeys through the air like an aëronaut. These ballooning spiders are frequently very abundant, especially in warm autumn days. At such times innumerable threads can be seen streaming from fences, from bushes, and the tips of stalks of grass, or floating through the air. The ballooning spider climbs to some elevated point, which may be merely the tip of a stalk of grass, and then, standing on the tips of its feet, lifts its body as high as it can, and spins out a thread of silk. This thread is carried up and away by a current of air. When the thread is long enough, the force of the air current on it is sufficient to buoy the spider up. It then lets go its hold with

its feet and sails away. That these spiders travel long distances in this manner has been shown by the fact that they have been seen floating through the air at sea far from land.

A NOISELESS, PATIENT SPIDER.

A noiseless, patient spider,
I mark'd where, on a little promontory, it stood isolated;
Mark'd how, to explore the vacant, vast surrounding,
It launch'd forth filament, filament, filament out of itself;
Ever unreeling them—ever tirelessly speeding them.

And you, O my soul, where you stand,
Surrounded, surrounded, in measureless oceans of space,
Ceaselessly musing, venturing, throwing—seeking the spheres, to connect them;
Till the bridge you will need be form'd—till the ductile anchor hold;
Till the gossamer thread you fling catch somewhere, O my soul.

Walt Whitman.

THE COBWEB-WEAVERS.

Many are the kinds of webs spun by different spiders. Some of them, as the orb-webs and the funnel-webs, delight us with their wonderful regularity of form, while others appear to be a mere shapeless maze of threads. Such are the structures whose presence in the corners of our rooms torment thrifty housewives, and which are disrespectfully termed cobwebs.

Although the house spiders are the most familiar members of this family, the greater number of species spin their webs in the fields on bushes. These webs usually consist of a flat or curved sheet, under which the spider hangs back downward. This sheet

is supported by threads running in all directions to the neighboring objects. Frequently there is a large number of these supporting threads above the web, which serve the additional purpose of impeding the flight of insects and causing them to fall.

Some of these spiders do not remain in their webs, but have a nest in a neighboring crack or corner, from which they rush to seize their prey. And sometimes there is a funnel-shaped tube leading to this nest. But these spiders differ from the true funnel-web weavers in running back downward on the lower side of their web.

FIG. 195.

The cobweb-weavers are small spiders with unusually slim legs. Fig. 195 represents a common species.

IN A GARRET.

Here, in the summer, at a broken pane,
The yellow wasps come in, and buzz and build
Among the rafters; wind and snow and rain
All enter, as the seasons are fulfilled.

Here where the gray incessant spiders spin,
Shrouding from view the sunny world outside,
A golden bumblebee has blundered in
And lost the way to liberty, and died.

*Elizabeth Akers.**

THE RUNNING SPIDERS.

There are certain large, dark-colored, hairy spiders that are common by roadsides, running over the ground or lurking under stones and fences. These spiders frequently attract attention by drag-

* By permission of Messrs. Charles Scribner's Sons.

ging after them a large gray ball (Fig. 196); this is the egg-sac which the female carries about with her

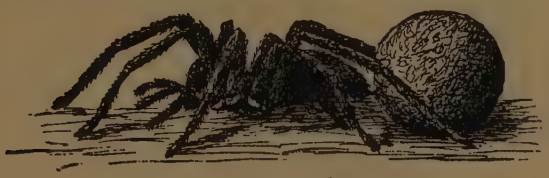

FIG. 196.—*Lycosa* and egg-sac.

attached to her spinnerets. These spiders run swiftly, and as they depend on the use of their legs for the capture of their prey they are called running spiders.

The larger members of our common species belong to the genus *Lycosa* (*Ly-co'sa*). These drag after them their egg-sacs, as described above; and when the young hatch they climb on their mother's back and are carried about for a time. The females of the genus *Dolomedes* (*Dol-o-me'des*), which also belongs to the family of running spiders, carry their egg-sac in their mandibles until the young are ready to hatch. At this time the mother fastens the egg-sac in a bush and spins a web of irregular threads about it, among which the young spiders remain for a time.

FIG. 197.

THE JUMPING SPIDERS.

The jumping spiders are of medium size, with a short body, and short, stout legs (Fig. 197). They are common on plants, logs, fences, and the sides of buildings. They are very apt to attract attention by their peculiar appearance, their short, stout legs, bright colors, conspicuous eyes, and quick, jumping move-

ments being very different from those of ordinary spiders. These self-possessed spiders are able to stare an ordinary observer out of countenance. They move sidewise or backward with great ease, and can jump a long distance. They stalk their prey, and make no webs except nests, in which they hide in winter or when molting or laying eggs.

THE CRAB-SPIDERS.

There are certain spiders which are called crab-spiders, on account of the short and broad form of the body, and the curious fact that they can walk more readily sidewise or backward than forward.

These spiders spin no webs, but lie in wait for their prey. They live chiefly on plants and fences, and in the winter hide in cracks and under stones and bark. Most of the species are marked with gray and brown, like the bark upon which they live. Some species conceal themselves in flowers, where they lie in wait for their prey. These are brightly colored, like the flowers which they inhabit, so that insects visiting flowers may alight within reach of a spider before seeing it.

FIG. 198. *Misumena vatia.*

One of the best-known members of this family is the female of *Misumena vatia* (*Mi-su-me'na va'ti-a*). This is milk-white, with sometimes a light crimson mark on each side of the abdomen, and is found within flowers (Fig. 198).

THE TARANTULAS AND THE TRAP-DOOR SPIDERS.

Those who live in the warmer parts of our country know well the large spiders commonly called ta-

rantulas. These are the giants among spiders, some of them being the largest known; but some species of this family are not very large. They are dark-colored, hairy spiders, and can be distinguished from the other families mentioned here by the fact that the claw of the mandibles works up and down instead of sidewise.

The members of this family do not construct true webs, but they dig long tubes in the earth which they line with silk, or line their hiding places in clefts in trees or elsewhere with a layer of silk. They live only in warm countries.

One of the best known of the tarantulas is *Eurypelma hentzii* (*Eu-ryp'el-ma hentz'i-i*). This species occurs in the South and in the Middle West, and is the largest of our spiders (Fig. 199). Several closely allied species are found in California.

But the members of this family that have attracted most admiration on account of their habits

FIG. 199.—A tarantula, *Eurypelma hentzii*.

are the trap-door spiders. These dig a tube in the ground, as do many other members of this family;

but this tube is lined with a denser layer of silk, and is provided with a hinged lid, which fits the opening of the tube with wonderful accuracy (Fig. 200). There are two small holes in the edge of the lid farthest from the hinge; when the spider enters its nest it runs over the door, and, catching the claws of its hind legs into these holes, pulls the door shut after it. The spider hides in this nest when not seeking

FIG. 200.—Entrance to nest of a trap-door spider.

its prey. Some species take the precaution to build a branch to their nest, and to provide this branch with a door. As this door forms a part of one side of the main tube, it is not likely to be observed by any creature which may find its way past the first door of the nest.

Several species of trap-door spiders occur in the Southern and Southwestern States.

THE HARVESTMEN OR GRANDFATHER-GRAYBEARDS.

Among the more common frequenters of roadsides are the harvestmen, which are near relatives of spiders. They differ from spiders, however, in having the abdomen segmented. Most harvestmen can be recognized by their very long and slender legs

(Fig. 201), although some species have comparatively short ones. They feed on small insects, especially aphids, and are perfectly harmless.

FIG. 201.

It is a common practice with children to catch these creatures and say to them, "Grandfather-gray-beard, tell me where the cows are or I'll kill you!" As the poor frightened animal points its legs in all directions in its frantic efforts to escape, it usually earns its freedom, but too often it is not without the loss of one or more legs.

THE LOCUSTS, GRASSHOPPERS, AND CRICKETS.

The locusts, grasshoppers, and crickets are the most universally common and conspicuous of the roadside insects; for at any time, from early spring to late autumn, some of them can be found by any grassy roadside.

These three groups of insects constitute three closely related families of the order Orthoptera, which are characterized on pages 72–74. They all agree in having the hind legs fitted for jumping, but differ in the form of the antennæ and of the ovipositor, and in the number of segments in the tarsi.

The crickets are generally known as such, but confusion exists in the common names of the other

two families, for most people that have not made a special study of insects do not make any distinction between the locusts and the true grasshoppers, but call the members of both families grasshoppers. On this account the locusts are sometimes called the short-horned grasshoppers, and the true grasshoppers are distinguished as the long-horned grasshoppers.

The pupil should collect specimens of each of the three families, and, after studying the descriptions on pages 72–74, label these specimens properly and place them in his collection.

FIG. 202.—A locust and a grasshopper.

Which of the two insects represented in Fig. 202 is a true grasshopper?

If the pupil has not already done so, a series of specimens of either locusts, grasshoppers, or crickets which illustrates incomplete metamorphosis should be collected. See Lessons XII and XIII.

Frequently small red parasites are found clinging to locusts; these are mites. See page 56.

Many locusts and grasshoppers exhibit what is known as protective coloring—that is, their colors are such as to protect them from birds when at rest in their usual haunts. Thus the true grasshoppers, which live among the blades of grass or the foliage of shrubs and trees, are usually green, while many locusts that rest on the ground are of the same color as the soil.

Collect specimens illustrating this.

Certain species of locusts are very liable to be destroyed by a fungous disease. The victims before

dying climb up some weed, to which they cling so firmly in their death grip that their bodies remain clinging to the plant long after death. Find specimens of locusts that have been killed in this way and preserve them with the part of the plant to which they are clinging.

THE GRASSHOPPER AND THE CRICKET.

The poetry of earth is never dead:
When all the birds are faint with the hot sun,
And hide in cooling trees, a voice will run
From hedge to hedge about the new-mown mead:
That is the grasshopper's—he takes the lead
In summer luxury—he has never done
With his delights; for, when tired out with fun,
He rests at ease beneath some pleasant weed.
The poetry of earth is ceasing never:
On a lone winter evening, when the frost
Has wrought a silence, from the stove there shrills
The cricket's song, in warmth increasing ever,
And seems to one in drowsiness half lost,
The grasshopper's among some grassy hills.

John Keats.

THE SONGS OF INSECTS.

Comparatively little is known regarding the songs of insects, if under this head we include all the sounds produced by these creatures. In a few instances the way in which the sounds are produced and the apparent object are understood; but in the great majority of cases this is not so.

Flies buzz when on the wing, but why? It may be that the sound is merely incident to the rapid motion of their wings, and means no more than the hum of rapidly moving machinery. But this can hardly

be true of the sounds produced by bees. The careful student of the honey-bee soon learns a language which is as intelligible to him as spoken words. The contented hum of the worker gathering pollen and nectar is very different from the savage buzz of the same individual when threatening an intruder who is disturbing the hive. So also is the sound produced by a queenless colony very different from that produced by one that has not this misfortune. The sound produced by bees emerging from any number of hives when merely the ordinary labor is going on would not be mistaken for the tumult caused by a single swarm leaving its hive for a new home.

Still, perhaps the only meaning of these various sounds is that the bees move in a different way when influenced by different emotions, and that the production of a peculiar sound is merely incidental and is not the object of the peculiar motion.

There are insects, however, in which distinct musical organs are developed, and that make movements that have for their sole object the production of sound. It is to these singers that we will turn our attention.

Chief among them are the cicadas, locusts, grasshoppers, and crickets. In all of these it is only the males that sing, these insects resembling the songbirds in this respect. We will study here only the musical organs of Orthoptera.

Locusts produce sounds in two ways:—First, certain species rub the inner surface of the hind femora, upon which there is a row of minute spines, against the outer surface of the fore wings. In this case each fore wing serves as a fiddle and each hind leg as a fid-

dle-bow. Second, other species rub together the upper surface of the front edge of the hind wings and the under surface of the fore wings. This is done while the locust is flying, and the result is a crackling sound. Third, the males of the different kinds of true grasshoppers, including the katydids, are provided with an elaborate musical apparatus, by means of which they call their mates. This consists of a peculiar arrangement of the veins and cells of a portion of each fore wing near its base. This arrangement differs in the different species, but in each it is such that by rubbing the fore wings together they are made to vibrate, and thus produce the sound. Fig. 203 represents a fore wing of the male of a common meadow grasshopper, and Fig. 204 that of a female of the same species.

FIG. 203.—Wing-cover of male meadow grasshopper.

FIG. 204.—Wing-cover of female meadow grasshopper.

Of all the insect musicians the crickets are most easily observed; we will therefore select them for our special study:—

1. Collect some crickets with fully developed wings and bring them alive to school.

2. Note that some of the crickets have a long, spear-shaped organ at the hind end of the body: these are the females and this organ is the ovipositor. The males differ from the females, not only in lacking the ovipositor, but also in the form of the front wings.

3. Prepare a breeding cage by placing a sod of growing grass in it, put several living male crickets in it, and set the cage where the insects can be watched. After the insects have become used to the cage they will chirp, and the pupils can determine how it is done.

4. Kill a pair of crickets by placing them in a cyanide bottle and then study their wings. How do the front wings of the male differ from those of the female? Make drawings showing the differences.

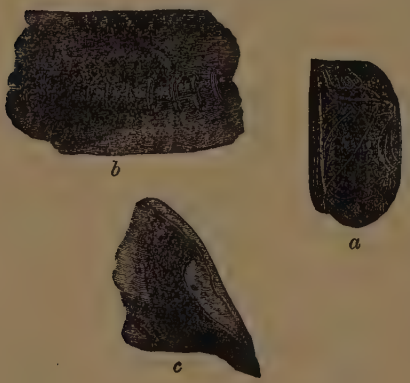

FIG. 205.—Musical organs of a male cricket.

5. If you have the use of a microscope observe that the principal vein which extends diagonally across the base of the fore wing of the male (Fig. 205, *a*) is furnished on the lower side of the wing with ridges like those of a file (Fig. 205, *b*); and that on the inner margin of this wing, a short distance toward the base from the end of the principal vein, there is a hardened portion, which may be called the scraper (Fig. 205, *c*).

6. Watch a cricket while chirping and determine how the files and scrapers of the two fore wings are used.

7. Write an account of the way in which crickets chirp.

Plate XIV

Plate XIV.—Tiger-moths.

(See page 239.)

FIGURE

1. The Bella-moth, *Utetheisa bella.*
2. The Trigonal Tiger-moth, *Zatrephes trigona.*
3. The Great Leopard Moth, *Ecpantheria ocularia.*
4. The Arge Tiger-moth, *Eyprepia arge.*
5. The Nais Tiger-moth, *Eyprepia nais.*
6. The Hickory Tiger-moth, *Halisidota caryæ.*
7. The Clymene Tiger-moth, *Haploa clymene.*

KATYDID.

I love to hear thine earnest voice,
Wherever thou art hid,
Thou testy little dogmatist,
Thou pretty katydid!
Thou mindest me of gentle folks—
Old gentle folks are they—
Thou say'st an undisputed thing
In such a solemn way.

Oliver Wendell Holmes.

CATERPILLARS, MOTHS, AND BUTTERFLIES.

The Tiger-moths.

Among the very many kinds of caterpillars that may be found by roadsides, the most common and most widely distributed are the larvæ of certain tiger-moths. These larvæ are densely clothed with hair, and are often found running over the surface of the ground; for many species seem to have but little choice of food plant, but roam free like cattle in a pasture. When full grown these larvæ spin cocoons, which are composed of the hair of the larvæ fastened together with a thin warp of silk. The adults are called tiger-moths because many of the species are conspicuously spotted.

The tiger-moths constitute the family ARCTIIDÆ (Arc-ti'i-dæ). There is not space here to describe other moths that occur by roadsides.

In collecting these larvæ for breeding observe in the case of each species whether it is restricted to some particular kind of plant or not. In the former case the breeding cage should be supplied with that kind of plant, but in the latter case a sod of grass will probably furnish the larvæ satisfactory food.

The most commonly observed species of these insects are the following:—

The Isabella tiger-moth, *Pyrrharctia isabella* (*Pyr-rharc'ti-a is-a-bel'la*).—The larva of this species is the evenly clipped, furry caterpillar, reddish brown in the middle and black at each end, which is seen so commonly in the autumn and early spring (Fig. 206). The adult is of a dull grayish tawny yellow, with a few black dots on the wings.

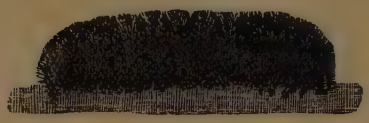

FIG. 206.

The yellow-bear *Spilosoma virginica* (*Spil-o-so'ma vir-gin'i-ca*).—The larva of this species is one of the most common hairy caterpillars found feeding on herbaceous plants. It is clothed with yellow hairs, which are very uneven in length, and which vary greatly in color in different individuals. The moth (Fig. 207) is snowy white, with the wings marked by a few black dots; these vary in number, but there are rarely more than three on each wing.

FIG. 207.—*Spilosoma virginica.*

The salt-marsh caterpillar, *Estigmene acræa* (*Es-tig-me'ne a-cræ'a*).—This species is not restricted to salt-marshes, as its name might indicate, but is widely distributed throughout the Uni-

FIG. 208.—*Estigmene acræa.*

ted States. The moth (Fig. 208) is white, marked with yellow and black. The sexes differ greatly in the ground color of the wings; in the female this is white throughout; in the male only the upper surface of the fore wings is white, the lower surface of the fore wings and the hind wings above and below being yellow.

FIG. 209.—*Eyprepia virgo.*

The most striking in appearance of our common tiger-moths belong to the genus *Eyprepia* (*Ey-pre'pi-a*). Of these there are many species. Fig. 209 represents one of the larger ones. In these insects the fore wings are velvety black, marked with yellowish or pink bands; in some species the lighter color predominates, so that the fore wings appear to be yellow or pink spotted with black.

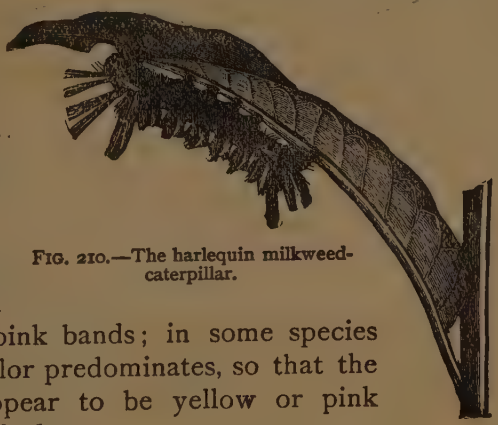

FIG. 210.—The harlequin milkweed-caterpillar.

The harlequin milkweed-caterpillar, *Cycnia egle* (*Cyc'ni-a eg'le*).—This larva is the most common caterpillar found on milkweed. It is clothed with tufts

of orange, black, and white (Fig. 210). The adult has mouse-gray, unspotted wings.

MOTHS.*

Ghosts of departed wingèd things,
What memories are those
That tempt you with your damask wings
Here where my candle glows?

Vainly you hover, circling oft
The tongue of yellow flame:
A tiger by caresses soft
You vainly seek to tame.

Here is no hope for you: nay, here
Death lurks within the light,
To leap upon you flying near
And sweep you from the night.

Moon-butterflies, back to your blooms
Born of the dew and stars!
Hence, ghosts, and find again your glooms
Hidden by shadow-bars.

Quick—speed across the dusky blue,
Lest, in a sudden breath,
This tawny tiger wake, and you
Endure a second death!

Frank Dempster Sherman.

THE SWALLOW-TAIL BUTTERFLIES.

These magnificent butterflies are easily recognized by their large size and the tail-like prolongations of the hind wings. The ground color of the wings is black, which is usually marked with yellow,

* From Lyrics for a Lute, by permission of Messrs. Houghton, Mifflin & Co.

Plate XV

Plate XV.—SWALLOW-TAIL BUTTERFLIES.

FIGURE

1. The Black Swallow-tail, *Papilio polyxenes*. See page 243.
2. The Tiger Swallow-tail, *Jasoniades glaucus*. See page 243.

[illegible] See page 313
[illegible] See page 313

and often with metallic blue or green; sometimes the yellow markings are more conspicuous than the black ground color. The swallow-tails belong to the family PAPILIONIDÆ (Pa-pil-i-on'i-dæ). The following well-known species will serve as illustrations:—

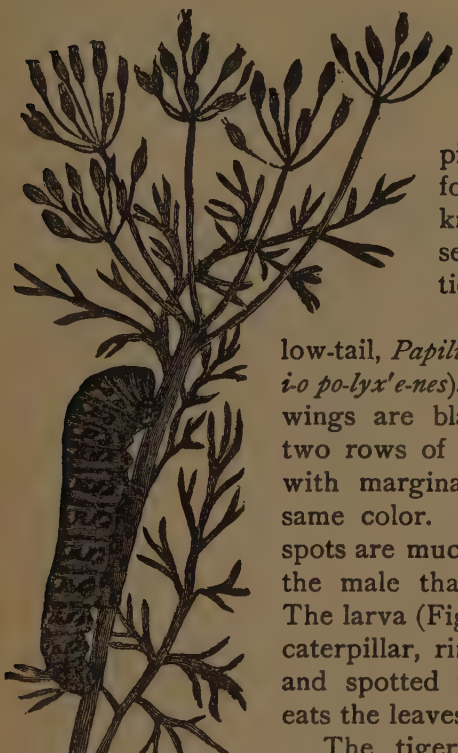

FIG. 211.—Larva of the black swallow-tail.

The black swallow-tail, *Papilio polyxenes* (*Pa-pil' i-o po-lyx' e-nes*).—In the adult the wings are black, crossed with two rows of yellow spots, and with marginal lunules of the same color. The two rows of spots are much more distinct in the male than in the female. The larva (Fig. 211) is the green caterpillar, ringed with black and spotted with yellow, that eats the leaves of caraway.

The tiger swallow-tail, *Jasoniades glaucus* (*Jas-o-ni'a-des glau'cus*).—This is the very common large swallow-tail with yellow wings. On the fore wings there are four black bars extending back from the costa; the inner one of these crosses the hind wings also. In the South there are two forms of the fe-

male; in the second form the disk of the wings is entirely black, but the black bands of the other form are faintly indicated by a darker shade. The larva of this species is represented by Fig. 212. It has the curious habit of weaving upon a leaf a carpet of silk, upon which

FIG. 212.—Larva of the tiger swallow-tail on its bed.

FIG. 213.—The zebra-swallow-tail.

it rests when not feeding; when nearly full grown, instead of spinning a simple carpet as before, it stretches a web across the hollow of a leaf, and thus makes a spring bed upon which it sleeps.

The zebra swallow-tail, *Iphiclides ajax* (*Iph-i-cli'des a'jax*).—This butterfly (Fig. 213) has the wings crossed by several bands of greenish white. Three distinct forms of this species occur; these differ in size, in the length of the tails of the hind wings, and in the time of appearance. The one figured here is the early-spring form.

THE WHITES AND THE YELLOWS.

These are the most abundant of all our butterflies, being common everywhere in fields and roads. They are usually of medium size, but some of them are small. They belong to the family PIERIDÆ (Pi-er'i-dæ).

FIG. 214.—A cabbage-butterfly.

THE WHITES.—The more common representatives of this group are the well-known cabbage-butterflies. The most widely distributed species is *Pieris rapæ* (*Pi'e-ris ra'pæ*). Fig. 214 represents the

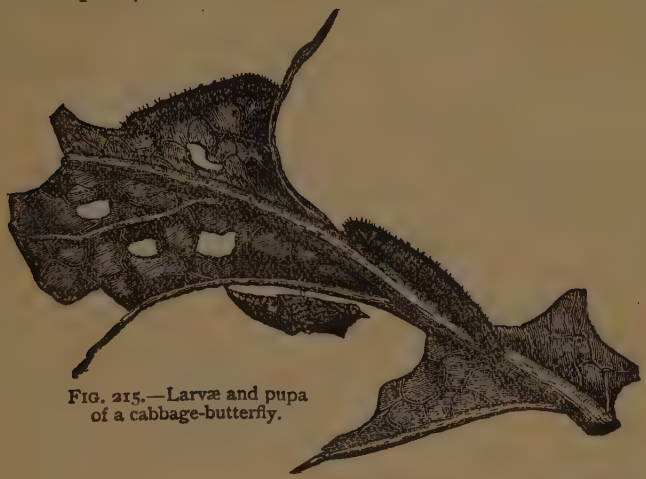

FIG. 215.—Larvæ and pupa of a cabbage-butterfly.

male; in the female there are two spots on the outer part of the fore wing, besides the black tip. In Fig.

215 two larvæ and a chrysalis are represented on a cabbage leaf.

THE YELLOWS.—The yellows are easily recognized by their bright yellow colors, although in some species whitish forms occur. They abound almost everywhere in open fields, and are common in wet places in roads. Fig. 216 represents the male of a common species; in the female the border on the fore wings is broader, and contains a submarginal row of yellow spots. This species is dimorphic. The second form is represented only by the female sex, and differs in having the ground color of the wings white instead of yellow. The larva feeds on clover and allied plants.

FIG. 216.—A yellow.

THE GOSSAMER-WINGED BUTTERFLIES.

There are certain butterflies, many of which are common by roadsides, that are of small size and delicate structure. These constitute the family LYCÆNIDÆ (Ly-cæn'i-dæ), or gossamer-winged butterflies. They resemble in size the smaller skippers (see page 81), but can be distinguished at a glance from the skippers by their delicate wings and more slender bodies. Our common species are grouped under three heads—the coppers, the blues, and the hair-streaks.

THE COPPERS.—The coppers are easily distinguished from other gossamer-winged butterflies by

Larva feeds on spice bush.

Plate XVI.—BUTTERFLIES.

FIGURE

1. The Baltimore, *Euphydryas phaeton.*
2. An Orange-tip, *Anthocharis stella.*
3. The Green-clouded Swallow-tail, *Euphœades troilus.* The larva feeds on spice bush.
4. The Dog's-head, *Zerene cæsonia.* The larva feeds on clover.

Plate XVI

their orange-red and brown colors, each with a coppery tinge, and conspicuous black markings. Fig. 217 represents a common species.

FIG. 217.—A copper.

THE BLUES.—The blues are so called on account of the blue color of the upper surface of the wings. The extent of this color, however, differs greatly in different species, and also in the two sexes of the same species. Fig. 218 represents the size and form of a common species.

FIG. 218.—A blue.

THE HAIR-STREAKS.—These are usually dark brown, with delicate striped markings on the lower surface of the wings, which suggested the common name given above; but some species are brilliantly marked with metallic blue or green. The hind wings are also commonly furnished with delicate tail-like prolongations (Fig. 219). The fore wings of the male often bear a small dull oval spot near the middle of the costal part of the wing—the discal stigma—which is filled with the peculiar scent-scales known as andriconia.

FIG. 219.—A hair-streak.

THE FOUR-FOOTED BUTTERFLIES.

The family NYMPHALIDÆ (Nym-phal'i-dæ), which includes a large proportion of our butterflies, differ

from all others in our fauna in having the fore legs very greatly reduced in size in both sexes. So great is the reduction that these legs can not be used for walking, but are folded on the breast like a tippet. A slight reduction in the size of the fore legs occurs in the Lycænidæ, but there it occurs only in the males and to a much less degree than in this family.

This is the largest of the families of butterflies. It not only surpasses the other families in number of species, but it contains a greater number and variety of striking forms and also a larger proportion of the species of butterflies familiar to every observer of insects. There may be in any locality one or two species of

FIG. 220.—The monarch.

yellows or of whites more abundant, but the larger number of species commonly observed are four-footed butterflies. The following are some of the more common forms:—

THE MONARCH.—The monarch, *Anosia plexippus* (*A-no'si-a plex-ip'pus*), can be recognized by Fig. 220. The larva feeds upon different species of milkweed. When full grown it is yellow, broadly banded with black, and bears a pair of long, fleshy filaments on the second thoracic segment and a similar pair on the seventh abdominal segment. The chrysalis is bright green, dotted with golden spots.

THE VICEROY.—The viceroy, *Basilarchia archippus* (*Bas-i-lar'chi-a ar-chip'pus*), resembles the monarch in color and markings, but can be distinguished by its smaller size and by the presence of a transverse black band on the hind wings (Fig. 221).

FIG. 221.—The viceroy.

Notwithstanding the close resemblance in appearance of these two insects, they belong to different subfamilies of butterflies, the viceroy exhibiting to a wonderful degree what is known as mimicry.

THE CRESCENT-SPOTS.—These are small butter-

flies, of which many species occur in this country. They are of a fulvous color, heavily marked with black. Each species varies considerably in markings, and different species resemble each other quite closely, making this a difficult group for the beginning student. Fig. 222 represents a common species.

FIG. 222.—A crescent-spot.

THE FRITILLARIES.—The fritillaries (frit'il-la-ries) is a group of butterflies including species varying from a little below to somewhat above medium size. The color of the wings is fulvous, bordered and checkered with black; the lower surface of the hind wings is often marked with curving rows of silvery spots. The larvæ feed upon the leaves of violets. Fig. 223 represents a common species.

FIG. 223.—A fritillary.

THE ANGLE-WINGS.—To this group belong many of our best-known butterflies. With these the outer

margin of the fore wings is usually decidedly angular or notched, as if a part had been cut away. A large proportion of the species hibernate in the adult state, and some of them are the first butterflies to appear in the spring. The following are some of our more common species:—

The red admiral, *Vanessa atalanta* (*Va-nes'sa at-a-lan'ta*).—The larva of this species feeds chiefly on nettle and on hop. The adult is represented by Fig. 224.

FIG. 224.—The red admiral.

The painted beauty, *Vanessa huntera* (*V. hun'-te-ra*).—The upper surface of this butterfly is represented by Fig. 225; on the lower surface there are two eye-like spots on each hind wing. The larva feeds on everlasting (*Gnaphalium*) and allied plants.

FIG. 225.—The painted beauty.

The cosmopolitan butterfly, *Vanessa cardui* (*V. car'-du-i*).—This butterfly resembles the preceding very closely in color and markings, but can be distinguished by the fact that on the lower surface of each hind wing there is a

submarginal row of four or five eyelike spots. The larva feeds on thistles and allied plants. This butterfly is distributed over the greater part of the world.

FIG. 226.—The American tortoise-shell.

The American tortoise-shell, *Aglais milberti* (*Ag'lais mil-ber'ti*).—The larvæ of this species feed upon nettle, and are gregarious in their early stages. The adult can be recognized by Fig. 226.

The mourning-cloak, *Euvanessa antiopa* (*Eu-va-nes'sa an-ti'o-pa*).—This butterfly (Fig. 227) is one of

FIG. 227.—The mourning-cloak.

the first to be seen in the spring, as it hibernates in the adult state. The larvæ live on willow, elm, poplar, and redbud; they are gregarious, and often strip large branches of their leaves.

Plate XVII.—BUTTERFLIES.

FIGURE

1. The Blue-eyed Grayling, *Cercyonis alope*. This is one of the Meadow-browns. See page 253.
2. The Violet-tip, *Polygonia interrogationis*. The larva feeds on hop, elm, and nettle.
3. The Spring Azure, *Cyaniris pseudargiolus*.
4. The Tailed Blue, *Everes comyntas*.
5. The American Copper, *Heodes hypophlæas*.
6. The Gray Hair-streak, *Uranotes melinus*.

Plate XVII

The compton-tortoise, *Eugonia j-album* (*Eu-go'ni-a j-al'bum*).—The upper surface of this species is represented by Fig. 228; on the lower surface of the hind wings there is a small L-shaped silvery bar.

FIG. 228.—The compton-tortoise.

There are several common angle-wing butterflies that resemble the preceding species in having a metallic spot on the lower surface of the hind wings, but differ in having the inner margin of the fore wings roundly notched beyond the middle. These belong to the genus *Polygonia* (*Pol-y-go'ni-a*).

FIG. 229.—A meadow-brown.

THE MEADOW-BROWNS.—There are several common butterflies that are brown in color and whose markings consist almost entirely of eyelike spots. As these are usually confined to grassy places, they are called the meadow-browns. One of them is represented by Fig. 229.

THE BUTTERFLY.*

Leafless, stemless, floating flower,
From a rainbow's scattered bower,
Like a bubble of the air
Blown by fairies, tell me where
Seed or scion I may find
Bearing blossoms of thy kind.—*John B. Tabb.*

THE BEES, WASPS, AND DIGGER-WASPS.

Throughout the summer and autumn the bees, wasps, and digger-wasps abound on the blossoms of roadside weeds. It requires some study and observation to distinguish these three groups of insects, but the pupils should learn to do so. Specimens of several species of each of these groups should be collected, properly labeled, and placed in the collection. All of these belong to the order Hymenoptera.

THE BEES.

The bees can be distinguished from all other Hymenoptera by the form of the basal segment of the hind tarsi (Fig. 230, *c*). This segment is more or less dilated, flattened, usually hairy, and bears an apparatus for collecting and carrying pollen. In some bees, however —those that do not make nests for themselves, but lay their eggs in the

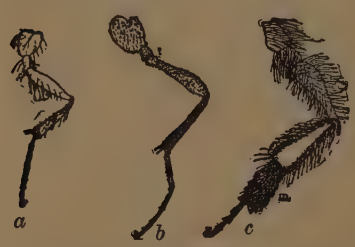

FIG. 230.—Legs of insects: *a*, wasp; *b*, ichneumon-fly; *c*, bee; *t*, trochanter; *m*, metatarsus.

* From Poems by John B. Tabb, by permission of Messrs. Copeland and Day.

nests of other bees—this segment is narrower, and is not furnished with organs for collecting and carrying pollen.

Some bees are solitary—that is, each female makes a nest for her own young. Several kinds of these will be described later. Here mention will be made only of the social bees—those kinds in which a large number of individuals work together to make a common nest. Of these there exist in this country the honey-bee and various species of bumblebees. These belong to the family APIDÆ (A'pi-dæ).

THE HONEY-BEE.—The honey-bees are constant visitors of roadside blossoms; here they are intently busy probing rapidly flower after flower as if they had not a moment to lose. Some amass great loads of yellow pollen on their hind legs, while others think only of gathering nectar. Some of them are plebeian black bees, while others bear the yellow bands at the base of the abdomen, characteristic of the more aristocratic Italian blood. The bees never seem satisfied with the yield of nectar; they drain a few florets on a spray of blossoms, and then, as if hoping to find a larger crop, they fly to another, only to repeat the operation a moment later.

As there are many special books on the honey-bee, we will not take the space to describe here the habits of this wonderful species. The best way to study it is to spend some time in an apiary with a practical beekeeper, and then continue the study by means of an observation hive, which can be obtained of most dealers in beekeepers' supplies. Such a hive can be placed in a schoolroom with its entrance at a window, and so arranged that the bees can not

enter the room, but admitting of free examination of the operations of the bees through the glass sides of the hive.

BEES.*

Bees don't care about the snow;
I can tell you why that's so:

Once I caught a little bee
Who was much too warm for me!

Frank Dempster Sherman.

THE BUMBLEBEES.—The clumsy, blundering bumblebees are one of the most characteristic features of roadside life. There are many kinds of them; more than fifty species have been described from North America alone.

With the bumblebees as with the honey-bee and with other social Hymenoptera, there are three forms of individuals in each species—the males or drones, the females or queens, and the workers. In the spring and early summer only queens are found; these are larger than the other two forms. A little later in the season the workers appear. There is a great variation in size of the workers of some species, but usually they can be easily distinguished from the queens by their smaller size. The males or drones are developed in the latter part of the summer. They resemble the workers in size, but differ in that the pollen baskets of the tibiæ of the hind legs are imperfectly developed. The fringe of hairs is not so long as in the workers, and there are scattered hairs over the surface of the tibia within the fringes.

* From Little-Folk Lyrics, by permission of Messrs. Houghton, Mifflin & Co.

In the latter part of the summer the pupils should collect the three forms of some of the more common species of bumblebees.

The nests of bumblebees are made in deserted mouse-nests. In early spring a queen finds a nest in which a mouse has passed the winter, and places within it a ball of pollen, upon which she lays some eggs. As soon as the larvæ hatch they eat into the pollen mass in all directions and, when full-grown, make for themselves silken cocoons and change to pupæ. These cocoons the old bees strengthen with wax, and after the young bees vacate them they are used as storing cells for honey. This explains the irregularity of the bumblebee-comb. The first broods of the season are workers, and relieve the queen of all duties except laying the eggs. Later in the summer males and young queens appear. In the autumn the colony breaks up, and all of the bees except the young queens perish. These crawl away into some protected place and pass the winter. In the spring each queen that has survived the winter founds a new colony, performing, until a brood of workers has been developed, both the duties of queen and of worker.

THE HOLLYHOCK.*

Seraglio of the Sultan Bee!
I listen at the waxen door,
And hear the zithern's melody
And sound of dancing on the floor.

Frank Dempster Sherman.

* From Lyrics for a Lute, by permission of Messrs. Houghton Mifflin & Co.

THE WASPS.

Many kinds of wasps and wasplike insects can be found on roadside flowers. The true wasps can be distinguished from the wasplike insects by the fact that when at rest they fold their wings lengthwise like a fan. Collect specimens of true wasps.

As with the bees, some of the true wasps are solitary, while other species are social.

THE SOLITARY WASPS.—The different species of solitary wasps vary greatly in habits. Some are miners, digging tunnels in the earth; some are carpenters, cutting tubular nests in wood, and showing a mason's skill by partitioning their tunnels off into cells with mud; while others are masons pure and simple, building oval or globular mud-nests, which they fasten to twigs of trees, the sides of buildings, or to other objects.

FIG. 231.—*Eumenes fraternus* and its nest.

The solitary wasps constitute the family EUMENIDÆ (Eu-men'i-dæ). In this family the tibiæ of the middle legs bear a single terminal spur, and the tarsal claws are armed with a tooth. A common represen-

tative of the family is *Eumenes fraternus* (*Eu'me-nes fra ter'nus*), which makes a neat little nest, appearing like a miniature water-jug, attached to a twig (Fig. 231).

THE SOCIAL WASPS.—The social wasps are the builders of the well-known paper nests. There are two types of these nests. In one the nest consists of a single comb, suspended by a peduncle, and is not inclosed by an envelope (Fig. 232).

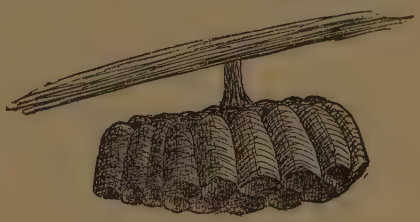

FIG. 232.—Nest of *Polistes*.

The wasps that build nests of this form belong to the genus *Polistes* (*Po-lis'tes*). In this genus the abdomen is long and spindle-shaped (Fig. 233). The species are black, ringed with yellow, or are brownish.

In the other type of nest there are several combs when the

FIG. 233.—*Polistes*.

FIG. 234.—Nest of *Vespa*.

nest is completed, and all are inclosed by a spherical paper envelope (Fig. 234). These nests are made by

wasps of the genus *Vespa*, which are commonly known as yellow-jackets, and as hornets. With these insects the body is comparatively short and stout (Fig. 235), and is black, spotted and banded with yellowish white.

Some species of *Vespa* attach their nests to buildings or to the branches of shrubs and trees. Such nests are made of a gray paper composed of fibers of weather-worn wood, which the wasps obtain from fences and the sides of unpainted buildings.

FIG. 235.—*Vespa.*

Other species build their nests in holes in the ground. These are usually composed of brownish paper which is quite fragile, being composed of more or less decayed wood. Owing to the fragile nature of this paper, the outer envelope of such nests consists of many small, shell-like parts fastened together, instead of large sheets.

The social wasps resemble the bumblebees in that a colony exists only one season; the males and workers die in the autumn, the young queens hibernate, and each starts a new colony in the spring, the queen at first performing the duties of both queen and worker. The social wasps belong to the family VESPIDÆ (Ves'pi-dæ).

THE DIGGER-WASPS.

There are several families of wasplike insects which have been classed together as the digger-wasps, because most of the species make nests for their young by digging burrows in the ground or in wood. These insects differ from the true wasps in that their wings lie flat above the body when at rest,

and they differ from the bees in not having the hind legs fitted for carrying pollen.

Although the digger-wasps do not provision their nests with pollen or nectar, they feed on these substances themselves, and hence are often found on flowers. Many of them are also frequently found in damp places collecting mud for their nests, for some species make their nests entirely of mud, and others that make burrows in wood divide these burrows into cells by partitions of mud.

Of those that build their nests of mud, the most common are the thread-waisted wasps, so called on account of the form of the first abdominal segment (Fig. 236). They make nests of mud attached to the lower surface of flat stones or to the ceilings of buildings. These nests usually have the form of several tubes an inch or so long placed side by side, and are provisioned with spiders. The spiders are not killed, but stung until paralyzed. The prey thus treated remains alive a long time, but is helpless. An egg is laid in each cell with this provision, and then the opening of the tube is sealed up securely. When the larva hatches it finds nicely preserved food right at hand sufficient to nourish it during its growth. Nests of other digger-wasps are described below.

FIG. 236.—A thread-waisted wasp.

INSECTS OF SUMACH AND OTHER PITHY PLANTS.

Many bees, wasps, and digger-wasps build their nests in dead branches of sumach and other pithy plants. Where sumach grows it affords the best opportunity for the study of the nests of these insects.

If the reader will go to the nearest clump of sumachs and break off a dozen dead branches, and then split them carefully, he is almost certain to find one or more such nests. Fig. 237 represents a common type of nest found in sumach.

FIG. 237.—Nest of *Trypoxylon frigidum*.

These nests are made by solitary insects—that is, a single female working alone builds a nest in which to lay her eggs. Representatives of several families utilize dead branches of pithy plants for this purpose. In such places can be found nests of solitary bees, of solitary wasps, and of digger-wasps.

The parent insect finds an entrance through a knothole at the side or at the end of the branch when the tip has been broken off. She excavates the pith for a considerable distance; then she collects a quantity of food and places it in the lower part of this tunnel, after which she lays an egg upon it, and builds a partition across the tunnel just above the egg and the supply of food. She repeats this process until the tunnel is divided into several cells, each containing an egg and a quantity of food.

When the larvæ hatch from these eggs each finds in its cell sufficient food to nourish it till it is full-grown. When this stage is reached the larvæ of some species spin cocoons about their bodies, within which the pupa state is passed; in other species the larvæ

change to pupæ without making cocoons. After a time the pupæ change to adult insects, which dig their way out from the nest, and in turn build similar nests for their young. In leaving the nest the newly developed adults pass out through the opening at the upper end. It follows from this that the youngest of the brood—the one in the cell last made—is able to emerge first, each adult being obliged to wait till those above it are out of the way before it can escape.

The nests of solitary bees can be recognized by the fact that they are provisioned with a paste made of pollen and nectar; and, so far as I have observed, the partitions in the nests of solitary bees are always made of vegetable matter. Sometimes the partitions are made of pith, sometimes of chewed-up leaves, and in the case of certain large carpenter-bees the partitions are built of small chips fastened together in a spiral.

The nests of the solitary true wasps and those of the digger-wasps are provisioned with animal matter, each species using a particular kind of food. Some use only spiders for this purpose, some plant-lice, some caterpillars, and so on through the list. In each case the creatures stored in the nest are not killed, but are stung in such a way as to be paralyzed. Here they lie helpless till needed as food by the larva that hatches from the egg laid with them.

The solitary wasps and the digger-wasps that build their nests in pithy plants also agree in usually making the partitions in their nests of mud. In fact, I know of no way of distinguishing between the nests of these two groups of insects except by breeding the adults. This, however, can be done easily.

When a nest of any of these insects is found containing either larvæ or pupæ, the adults can be bred by carefully closing the nest and placing it in a breeding cage, or, if it is too long, in a bag of Swiss muslin.

There are certain minute digger-wasps that do not need to remove all the pith from the section of the branch in which they make their nest. These make winding burrows in the pith. Fig. 238 represents one of these nests. Such nests are usually provisioned with plant-lice.

FIG. 238.

Some of the wood-burrowing bees and wasps are not so saving of their labor as those that burrow in pith, but make their tunnels in solid wood. Fig. 239 represents the nest of a solitary wasp which was made in a board in the side of a barn. The contents of the cells had been removed by the collector before the nest came into our possession, hence they are not shown in the figure. The partitions in this nest are made of mud. The archi-

FIG. 239.

tect of it is pictured in Fig. 240. Its name is *Monobia quadridens* (*Mo-no'bia quad'ri-dens*).

There are large carpenter-bees that make nests similar to that of *Monobia*, except that the partitions are formed of bits of wood fastened together. These bees resemble bumblebees in size and appearance, but differ in having a dense brush on the hind legs instead of a pollen basket.

FIG. 240.—*Monobia quadridens.*

The bees of the genus *Megachile* (*Meg-a-chi'le*) have the curious habit of making cells for their young out of neatly cut pieces of leaves, and on this account they are called leaf-cutter bees. The cells of the leaf-cutter bees are packed away in such secure places that one does not often find them, but it is a very easy thing to find fragments of leaves from which the pieces have been cut by bees. The leaves of various plants are used for this purpose, but rose-leaves are used more frequently than any other kind. In Fig. 241 there are represented one of these bees, its nest, and a spray of rose-leaves from which pieces have been cut by the bee.

The species represented here, *Megachile acuta* (*M. a-cu'ta*), is a carpenter as well as a leaf-cutter. It first makes a tunnel in wood, often selecting that which is partially decayed; then it proceeds to build a thimble-shaped tube at the bottom of this tunnel. For this purpose it cuts from the leaves oblong pieces, each of which forms a part of a side and the bottom of the thimble-shaped tube. Two such pieces had been cut from the lower leaf on the left

side of the spray figured here. When the thimble-shaped tube is completed, the bee partially fills it with a paste of pollen and nectar, and then places an egg upon the supply of food. She then cuts several circular pieces of leaves, the diameter of which is a

FIG. 241.—A leaf-cutter bee, nest, and rose-leaves cut by the bee.

little greater than the diameter of the tube, and forces them into the open end of it, thus making a tightly fitting plug; three of these circular pieces had been cut from the spray figured. Usually several cells of this kind are placed end to end in a burrow, and sometimes many bees will build their nests near together in the same piece of wood.

The leaf-cutter bees do not always bore tunnels in which to place their cells. We have found these cells in a crack between shingles on a roof, in the cavity of a large branch of sumach, beneath stones lying on the ground, and, in Florida, in the tubular leaves of the pitcher-plant.

Some species of bees make nests similar to those of the leaf-cutter bees, except that the cells are formed of pieces of petals of flowers. The petals of Pelargonium are often used for this purpose.

THE CLIFF-DWELLERS.

There are many bees, wasps, and digger-wasps that build their nests in the sides of cliffs, reminding one of the habitations built by certain communities of Indians in the far West. The insect cliff-dwellers prefer sandy cliffs, and it often happens that a sand-bank becomes so thickly studded with the burrows of these insects that it looks as if it had been used as a target for practice with a shotgun.

The most abundant of these cliff-dwellers are the minute bees belonging to the genus *Halictus* (*Ha-lic'-tus*). These are the smallest of all our bees, measuring only from one tenth to three tenths of an inch in length. Great numbers of them can be seen during the warmer parts of the day, flying back and forth,

close to the face of the cliffs inhabited by them. The openings to their burrows are just large enough for a bee to enter, but a short distance from the opening the burrow is enlarged so that a bee can turn about in it easily. This feature and the small size of the opening distinguish the burrows of *Halictus* from those of other common cliff-dwellers. In the sides of this comparatively large burrow there are many small openings leading into cells, in each of which is placed a supply of food and an egg. The walls of these cells are glazed like the surface of pottery. It is said that several females unite in making the larger burrow, after which each female makes passages extending sidewise from this main burrow or public corridor to her own cells. If this is true a cliff inhabited by *Halictus* may be compared to a city composed of apartment houses.

Certain cliff-dwelling bees, which are much larger than *Halictus*, resembling the honey-bee in size, conceal the entrance to their burrows by building over each a tube which is bent downward.

Some solitary wasps and many species of digger-wasps are cliff-dwellers. The nests of these can be recognized by the fact that they are provisioned with insects or spiders.

THE MINERS OF THE PLAINS.

Although the sides of sandy cliffs afford the mining insects the best of conditions for building their nests, both as regards the economy of labor and in protection from drenching rains, there are many species that prefer to mine in level ground. The following are among the more common of these:—

THE MINING-BEES.—The bees of the genus Andrena (*An-dre'na*) probably attract attention more frequently than any other mining-bees. Some of the species nearly or quite equal in size the workers of the honey-bee. They build their nests in grassy fields, sinking a perpendicular shaft with branches leading sidewise to the cells. The main shaft sometimes extends to a depth of more than one foot. These bees, though strictly solitary—each female building her own nest—frequently build their nests near together, forming large villages. Sometimes a village, or we might say a city, of this kind, covering only one square rod of ground, will include several thousand nests.

THE MINING DIGGER-WASPS.—Various digger-wasps build their nests in level ground, especially in sandy places. One family of these are known as the spider-wasps, because they provision their nests with spiders. The spider-wasps belong to the family POMPILIDÆ (Pom-pil'i-dæ); they are slender in form, with long legs (Fig. 242), and are usually black with dusky reddish or black wings; sometimes they are variegated with red or orange. They are common everywhere throughout our country, and are often seen on bright, hot days running about with a jerky step and constantly twinkling wings; even when at rest the wings are frequently twitched. It is a common thing also to see these digger-wasps running backward, dragging their prey after them. A very large species which occurs in the Southwest is known as the tarantula-hawk, because it stores its burrows with tarantulas.

FIG. 242.

Another very large digger-wasp which frequently attracts attention is represented by Fig. 243. This is the cicada-killer, *Sphecius speciosus* (*Sphe'ci-us spe-ci-o'sus*). It is black, sometimes of a rusty color, and has the abdomen banded with yellow. It digs burrows in the earth two feet or more in depth, and provisions each with a cicada.

FIG. 243.—*Sphecius speciosus.*

THE TIGER-BEETLES.—The tiger-beetles are long-legged, agile beetles, which abound on bright, hot days in dusty roads, in beaten paths, and on the shores of streams. Fig. 244 represents a common species. Their popular name was suggested by their predaceous habits and the stripes with which many species are marked. They can run swiftly and fly well. When approached by a passer-by, they remain quiet but alert till nearly reached; then like a flash they fly up and away, but alight after going a few rods. Before alighting they always turn so as to face the approaching person and be able to watch his movements.

FIG. 244.

These beetles dig sloping burrows in the earth into which they retreat in stormy or cold weather.

The larvæ of the tiger-beetles live in vertical bur-

rows, which can be easily recognized after one has learned their characteristic appearance. These burrows abound in sandy places, in beaten paths, and in plowed fields that have become dry and hard. The larger ones, those occupied by full-grown larvæ, measure about one sixth inch in diameter, and often extend a foot or more in depth. The sides are smooth; the entrance to each is very regular in outline, and without any loose dirt on the surface of the ground near it, as is usually the case with somewhat similar burrows made by ants.

FIG. 245.

Fig. 245 represents a larva of a tiger-beetle. When watching for its prey, the larva rests perfectly still at the mouth of its burrow. Its dirt-colored head is bent at right angles to its lighter-colored body and makes a neat plug to the opening of the hole. Its rapacious jaws extend upward, wide open, ready to seize the first unwary insect that walks over this living trap. On the fifth segment of the abdomen there is a hump, and on this hump are two hooks curved forward. This is an arrangement by which the little rascal can hold back and keep from being jerked out of its hole when it gets some large insect by the leg, and by which it can drag its struggling prey down into its lair, where it may eat it at leisure.

The holes of the tiger-beetle larvæ are always open when found, the larvæ being frightened away by the approach of the observer. But sit down near them, and watch quietly, and soon they will be plugged by dirt-colored heads. Each passer-by will cause the cautious larvæ to retreat; but they will re-

turn in a few minutes to their position of patient watchfulness, and here they wait like a still fisherman on a log.

The habits of these larvæ can be observed in a schoolroom in the following manner:—

1. Take a box about eight inches deep, and half fill it with sand or fine earth, and pour some water on the soil so that it shall become packed firmly.

2. Collect several tiger-beetle larvæ. In doing this put a stalk down the burrow so that it shall not become filled with dirt, and thus lost while you are digging the larva out. Put each larva collected in a single vial, so that they can not injure each other.

3. With a slender stick or a slate pencil make holes in the soil in your box, one or two inches deep and about as wide as burrows of tiger-beetle larvæ, and put a larva in each.

FIG. 246. Goldenrod, *Solidago*.

4. Observe the way in which the larvæ deepen these holes, and fit them for their use.

5. When the larvæ have become well established in their new burrows, scatter sugar on the surface of the soil so as to attract flies.

6. Make notes on the habits of tiger-beetle larvæ, and write an account of them.

INSECTS OF GOLDENROD.

In late summer and in the autumn the yellow blossoms of the goldenrod attract swarms of insects of various kinds; at this season there is no better field for the collector than the clumps of this plant growing in the fence corners.

THE SOLDIER-BEETLES.—The most abundant of the goldenrod visitors are the soldier-beetles; so-called on account of the bright colors of their yellow and black uniforms (Fig. 247). Sometimes these beetles occur in such great numbers on the goldenrod blossoms as to bend the plant down by their weight. Here they are in constant motion, crawling over the plant and over each other. But they can fly readily, and do so often, passing from cluster to cluster. These beetles belong to the genus *Chauliognathus* (*Chaul-i-og'na-thus*), of the firefly family, LAMPYRIDÆ (Lam-pyr'i-dæ).

FIG. 247.

FIG. 248.

THE LOCUST-BORER. — Associated with the soldier beetles we often find one with his back covered with yellow stripes like the chevron on the sleeves of a sergeant (Fig. 248). This is the locust-borer, *Cyllene-robiniæ* (*Cyl-le'ne ro-bin'i-æ*). It belongs to the family of long-horned beetles.

THE BLISTER-BEETLES.—Blister-beetles are also frequently found on the flowers of goldenrod. With these the body is comparatively soft; the head is broad, and abruptly narrowed into a neck, and the prothorax is narrower than the wing-covers (Fig. 249). There are many kinds of blister-beetles; they constitute the family MELOIDÆ (Me-lo'i-dæ). They are called blister-beetles because the dried bodies of certain species are used for making blister plasters.

FIG. 249.

THE AMBUSH-BUG.—There is a greenish bug, with very strong fore legs and a broadly expanded abdomen (Fig. 250), which conceals itself in the flowers of goldenrod and in other flowers. This is the ambush-bug; it rests quietly among the flowers until some nectar-loving insect comes within its reach, when the visitor is seized and destroyed. The ambush-bug can overcome insects much larger than itself. Its name is *Phymata wolffii* (*Phy-ma'ta wolf'fi-i*), and it belongs to the family PHYMATIDÆ (Phy-mat'i-dæ).

FIG. 250.

THE GOLDENROD GALLS.—One of the most familiar of abnormal growths on plants is a ball-like enlargement of the stem of goldenrod (Fig. 251). This is caused by a maggot which lives within it, and which develops into a pretty fly with banded wings. The name of the fly is *Trypeta solidaginis* (*Try-pe'ta sol-i-dag'i-nis*), and its gall is designated as the round goldenrod gall.

FIG. 251.—The round goldenrod gall.

There is another gall on the stem of goldenrod which is more elongate and is hollow. This is known as the elliptical goldenrod gall; it is represented in the lower part of Fig. 246. This gall is made by the larva of a Tineid moth, *Gelechia gallæsolidaginis* (*Ge-le'-chi-a gal-læ-sol-i-dag'i-nis*).

Collect specimens of these galls, and, placing them in breeding-cages, rear the adult insects.

ANTS.

The most abundant of all roadside insects are the ants. Of these there are many kinds, each differing more or less from the others in appearance and in habits, but the following generalizations can be made:—

All ants are social, many individuals working together to make a common nest. As with the social bees and with the social wasps, each colony of ants consists of three classes of individuals: males, females or queens, and workers. The males and females are winged; the workers are wingless. The worker class is the one most often observed, this class constituting the greater number of individuals found in any nest. In fact, it is only during a part of the year that winged forms can be found in the nests, although wingless queens are constantly present.

Often in warm summer afternoons the air will seem to be filled with countless thousands of flying ants. Their moving wings divide the sun's rays into rainbow flashes as they rise or fall, a silent, onward-moving host. This is the wedding journey of the male and female ants, which have come from many communities and have taken flight together. But soon the journey is over and they drop to earth, where the males soon die; but the females tear off their own wings, having no further use for them, and set about to find places to lay their eggs. Sometimes a female starts a new colony; in other cases she is found by some workers of her own species and adopted as their queen.

The term queen, as applied to the individual at

the head of a colony of ants, is a misnomer, for among social insects the queens do not rule; they are merely the mothers of their colonies. The queen ant is not jealous, like the queen bee, but may live in peace in the same dwelling with several other queens. She is always an object of extreme devotion to her attendants, who feed her and care for her eggs as soon as she lays them.

The larvæ of ants are white and legless; most species spin cocoons when ready to pupate, but some do not. The oblong, egg-shaped bodies which may be seen in any ant's nest, and which are often mistaken by the careless observer for eggs, are these cocoons. The eggs are so small that they escape observation unless careful search is made for them. The larvæ are efficiently cared for by the workers, who carry them about and put them in the warmer parts of the nest and feed them. When the adults issue from their cocoons their nurses help them out carefully; and they unfold the legs and smooth out the wings of new-fledged royalty with tenderest solicitude. The workers are by far the most interesting portion of the ant colony, as they do all the work—feed the colony, build and defend the nests, care for the young and for the stock, and carry on the wars. The workers are undeveloped females, which very rarely lay eggs, and as the eggs of workers always develop into males, the presence of a queen is necessary for the perpetuation of the life of a colony. For this reason, as the queens grow old the workers find young queens at the swarming season, bring them into their nests, and adopt them as successors to the old queens.

There are many forms of ants' nests, but each species builds the same sort. Sometimes the nest is a simple tunnel in the earth, sometimes a large mound with tunnels and galleries extending many feet under ground, and some species live in decayed trees. In the tropics a greater variety of these structures occur than in our country. Some colonies own several mounds. One colony of one species has been known to have two hundred mounds, covering several hundred square yards. Ants are also very good road-makers, sometimes making clean, beaten paths, and sometimes working out covered ways under rubbish.

As to their food, ants are general feeders, eating animal food and also sweet substances, like the juice of fruit and sugar; and they are also very fond of the honey-dew given off by aphids, and the ants regard these aphids as their milch-cows. An ant will walk up to an aphid and stroke its back with its antennæ, and immediately the pleased aphid gives forth a drop of sweet fluid, which the ant at once drinks up. The ants take very good care of their cattle, and will carry them to new pastures if the old ones dry up. They also carry the aphid-eggs into their nests, and keep them sheltered during the winter, and then carry the young plant-lice out and put them on plants in the spring. When ants are seen going up and down the trunks of trees it is safe to suppose they are attending aphids. They also care similarly for some other honey-giving insects, as certain bark-lice (*Coccidæ*) and tree-hoppers (*Membracidæ*).

THE HABITS OF ANTS (*Field Work*).—Make a collection of ants representing as many species as practicable. Give each species a number, and make notes

on the kind of nest made by each. The smaller specimens should be mounted on cardboard points.

Look for ant-nests under stones lying on the surface of the ground, and when one is found containing eggs, larvæ, pupæ, and adults, collect a set of specimens illustrating the transformations of the species.

Find a shrub or tree upon the trunk of which ants are passing up and down. Watch some of the ants that are going up and determine the object of their journey. Follow some of the ants that are passing down till they reach their nest. It sometimes happens that ants have covered ways several rods in length leading from their nest to the trees that they frequent. If such a road be found, uncover it carefully till the nest is reached.

Write an account of what you have learned in the field regarding the habits of ants.

THE HABITS OF ANTS (*School Work*).—The habits of ants can be studied in a schoolroom by establishing a colony in an artificial nest. Such a nest is represented in Fig. 252. It is similar to one devised by Sir John Lubbock.

FIG. 252.—An artificial ant-nest.

The principal materials needed for the construction of a nest of this kind are two panes of window-glass ten inches square, a sheet of tin eleven inches square, and a piece of plank one and one fourth inches thick, twenty inches long, and at least sixteen inches wide.

To make the nest, proceed as follows: Cut a triangular piece about one inch long on its two short sides from one corner of one of the panes of glass.

From the sheet of tin make a tray three eighths of an inch in depth. This tray will be a little wider than the panes of glass and will contain them easily. On the upper side of the plank a short distance from the edge, cut a deep furrow. This plank is to form the base of the nest, and the furrow is to serve as a moat, which is to be kept filled with water, in order to prevent the escape of the ants. It is necessary to paint the base with several coats of paint to protect it from water and thus prevent its warping.

To prepare the nest for use, place the tin tray on the base, put in the tray the square pane of glass, lay on the edges of the glass four strips of wood about one half inch wide and a little thicker than the height of the ants which are to be kept in the nest, cover the glass with a layer of fine earth of the same thickness as the strips of wood, place upon this layer of earth and the strips of wood the pane of glass from which one corner has been cut, and cover the whole with a cover of the same size and shape as the upper pane of glass. In the nest figured the cover is made of blackened tin, and one half of it is covered by a board. This gives a variation in temperature in different parts of the nest when it stands in the sunlight.

The ants when established in the nest are to mine in the earth between the two plates of glass. The removal of one corner from the upper pane provides an opening to the nest. The thickness of the strips of wood between the edges of the two panes of glass determines the depth of the layer of earth in which the ants live. This should not be much thicker than the ants are high; for if it is the ants will be able

to conceal themselves so that they can not be observed.

The nest being prepared, the next step is to transfer a colony of ants to it. The things needed with which to do this are a two-quart glass fruit-can or some similar vessel that can be closed tightly, a clean vial, and a garden trowel. With these in hand, find a small colony of ants, such as are common under stones in most parts of the country. Collect as many of the ants and of the eggs, larvæ, and pupæ as possible, and put them in the fruit-can together with the dirt that is scooped up in collecting them with the trowel. Search carefully for the queen; sometimes she is found immediately beneath the stone covering the nest, but often it is necessary to dig a considerable distance in order to find her. She can be recognized by her large size. If the queen is not found, empty the contents of the can back into the nest, and take up another colony; without a queen the experiment will be a failure. When the queen is found place her in the vial so that she shall not be injured while being carried to the schoolroom.

Having obtained a queen and a large part of her family old and young, return to the schoolroom and empty the contents of the fruit-can on to the board covering the upper pane of glass, and place the queen there with her family. If much dirt and rubbish has been collected with the ants, remove some of it so that not more than a half pint of it remains. When this is done leave the ants undisturbed for a day or two. Of course the moat should be filled with water so that they can not escape.

Usually within twenty-four hours the ants will find the opening leading into the space between the two panes of glass and will make a mine into the layer of earth which is there, and will remove their queen and young to this place. This process can be hastened by gradually removing the dirt placed on the cover of the nest with the ants.

After the ants have made a nest between the panes of glass, they can be observed, when desired, by merely lifting the board forming the cover of the nest.

With proper care a colony can be kept in a nest of this kind as long as the queen lives, which may be several years. The food for the ants can be placed on the base of the nest anywhere within the moat, and may consist of sugar, minute bits of meat, fruits, etc. With a little care the kinds of food preferred by the colony can be easily determined. The pupæ of ants, which can be collected from nests in the field during the summer months, will be greedily devoured. The soil in the nest should be kept from becoming too dry by putting a little water into one side of the tin tray from time to time.

Many suggestions as to the kinds of experiments that can be tried with a colony of ants can be obtained by reading the well-known work of Sir John Lubbock entitled *Ants, Bees, and Wasps.*

O the South Wind and the Sun!
How each loved the other one—
Full of fancy—full of folly—
Full of jollity and fun!

How they romped and ran about,
Like two boys when school is out,
With glowing face, and lisping lip,
Low laugh, and lifted shout!

Over meadow-lands they tripped,
Where the dandelions dipped
In crimson foam of clover-bloom,
And dripped and dripped and dripped;
And they clinched the bumble-stings,
Gauming honey on their wings,
And bundling them in lily-bells,
With maudlin murmurings.

And the humming-bird, that hung
Like a jewel up among
The tilted honeysuckle-horns,
They mesmerized, and swung
In the palpitating air,
Drowsed with odors strange and rare,
And, with whispered laughter, slipped away
And left him hanging there.

And the golden-banded bees,
Droning o'er the flowery leas,
They bridled, reined, and rode away
Across the fragrant breeze,
Till in hollow oak and elm
They had groomed and stabled them
In waxen stalls that oozed with dews
Of rose and lily-stem.

Where the dusty highway leads,
High above the wayside weeds
They sowed the air with butterflies
Like blooming flower-seeds,
Till the dull grasshopper sprung
Half a man's height up, and hung
Tranced in the heat, with whirring wings,
And sung and sung and sung!

And they loitered, hand in hand,
Where the snipe along the sand
Of the river ran to meet them
As the ripple meets the land,
Till the dragon-fly, in light
Gauzy armor, burnished bright,
Came tilting down the waters
In a wild, bewildered flight.

*James Whitcomb Riley.**

* From Afterwhiles, by permission of the Bowen-Merrill Co.

PART II.

THE COLLECTION AND PRESERVATION OF SPECIMENS.

CHAPTER I.

THE COLLECTION OF SPECIMENS.

FIG. 253.

IN order to study insects thoroughly it is necessary to collect specimens. Very much can be learned by merely watching insects in the field, but if we are to study their structure and their classification, we must make a collection.

In doing this we should be humane. It is not probable that insects are as sensitive to pain as we are, but there is no doubt that they suffer when injured. We should, therefore, handle our specimens carefully, kill them without inflicting needless pain, and destroy no more than is necessary for study. It is not merely the insects that are to be considered in this matter, for no one can be cruel to animals without its having a bad effect on his character.

I. COLLECTING APPARATUS.

The first step in the collecting of insects is the preparation of collecting apparatus. Many things

have been devised for this purpose, and are in use by professional entomologists, but the beginner needs only a few of them. Usually a collecting outfit will consist of merely a net, a killing bottle, and a few vials or pill-boxes for bringing home living specimens. If one desires to collect butterflies it is well to add to this list a cork-lined collecting box and perhaps a vial of chloroform with a small brush fitted in the cork.

INSECT NETS.—Many insects can be easily and safely caught by hand, but it is desirable that some members of the class, and the more the better, should have insect-nets. The usual form of an insect net is shown in Fig. 253. Such a net is made as follows:—

The ring is of No. 3 galvanized iron wire, and is one foot in diameter. It is securely fitted into a light wooden handle, which is three feet and six inches in length. The ring is covered with a piece of strong cloth—ordinary sheeting—to which a bag of cheese-cloth is sewed. The strong cloth over the ring is necessary to prevent the net from wearing out quickly. The bag of the net should be longer than its diameter, so that when an insect is caught while flying it can be imprisoned in the bottom of the bag by simply rolling the handle of the net. The bottom of the bag should be rounded, without corners or points in which insects can lodge.

KILLING BOTTLES.—The specimens collected should be killed in some way that shall not mutilate them. This can be done by putting a few drops of chloroform, sulphuric ether, or benzene on cotton and inclosing it with the insects to be killed in a bottle or small box. But the most convenient way,

and the one that is commonly employed, is by the use of a cyanide bottle. Each pupil, except very young ones, should have such a bottle. The bottles can be prepared, either by the teacher or by a druggist, in the following manner:—

Take a wide-mouthed bottle holding four or six ounces. Put in this bottle a piece of cyanide of potassium, about three fourths of an inch square, and water enough to cover the cyanide; and then immediately, before there is time for the cyanide to dissolve, put enough plaster of Paris in the bottle to entirely soak up the water. In this way the cyanide will be firmly cemented in place in the bottom of the bottle. The bottle should then be left open in a shady place for an hour to dry, and then securely corked with a long cork and labeled *Poison*, after which it is ready for use (Fig. 254).

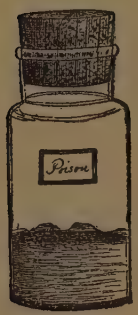

FIG. 254.

In using a cyanide bottle care should be taken not to leave it open unnecessarily, lest it lose its strength. With proper care a bottle will retain its strength for several months.

Specimens placed in the bottle to be killed should be left there for at least a half hour. They may be left in the bottle several hours, even over night, without injury. Thus a collecting trip may be made one day and the specimens left in the bottle till the following day before they are pinned. If it is necessary to return an insect to the cyanide bottle on account of its revival after it is pinned, the pin should be removed, for the gas in the bottle will corrode it.

A small cyanide bottle, about one fourth the size of that described above, is very convenient for carrying in one's pocket constantly during the collecting season. A very convenient pocket-bottle is represented half size by Fig. 255.

FIG. 255.

COLLECTING BOXES.—Collectors of butterflies usually have a shallow tin box, lined with pith or cork, into which specimens can be pinned, and fitted with a strap by means of which it can be slung over the shoulder (Fig. 256). A cheap substitute for such a box can be made by using a shallow cigar-box, lined with cork and fitted with a strong cord. Make a small hole in each end of the box, and through each hole put an end of the cord and tie a knot in it; tack a piece of sheet-cork to the bottom of the box on the inside, and the box is ready for use. If sheet-cork can not be obtained, the box can be lined with the pith of corn-stalks, or slices can be cut from cork stopples and tacked to the bottom of the box.

FIG. 256.—A collecting box.

FOLDED PAPERS FOR BUTTERFLIES.—There is another method of caring temporarily for specimens of butterflies, which is used when it is not convenient to pin them. The specimen is killed while it is yet in the net by pinching the thorax, care being taken that the wings are folded together above the back, so that they shall not be rubbed. Then the specimen is dropped into a triangular envelope made by folding

a piece of paper, as shown in Fig. 257, and a memorandum of the locality and date of capture is written

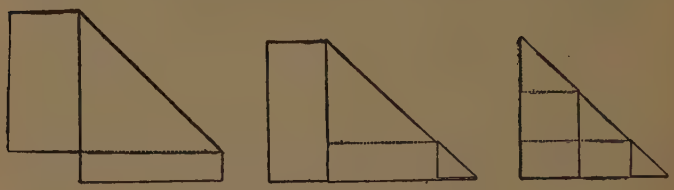

FIG. 257.—Folded paper for butterflies.

on the envelope. If one expects to use this method, it is well to have a shallow, flat tin box in which the envelopes can be carried without danger of breaking the specimens. When it is desired to pin and spread specimens that have been stored in this way they are relaxed by putting them on damp sand, as described in the next chapter.

VIALS AND PILL-BOXES.—A supply of vials and pill-boxes is desirable for almost every collecting trip; many delicate insects can be carried with safety in these that would be rubbed in a killing bottle; and, too, it is often desirable to carry home living specimens, especially of larvæ and pupæ. For collecting spiders and soft-bodied insects one or more small bottles or vials partly filled with alcohol are useful.

II. WHEN AND WHERE TO COLLECT INSECTS.

Although insects can be collected at all seasons of the year and at all times of the day and night, there are certain periods during which a very much greater variety can be obtained than at others.

Obviously the best season of the year is during the summer months; the best periods of the day are

between 8 A. M. and 2 P. M., and in the evening twilight. These are the times during which searching for insects in the fields will yield the largest returns. If, however, the collecting be restricted to these periods many species will escape notice. Many insects can also be collected after dark by enticing them to lights or sweetened baits.

While the careful collector will search for specimens in all manner of places, there are certain localities in which insects occur much more abundantly than in others. First in importance is upon herbage and shrubbery, where many species of plants are growing together, and especially upon the borders of woods. Open fields, which are covered chiefly by a single species of plant, and deep, dense forests furnish many interesting forms, but a much more limited variety. The banks and beds of ponds and streams are also excellent collecting places. A great variety of forms can be obtained from the lower surface of stones taken from the beds of streams. Many species may be found in the moss on the trunks of trees, beneath bark, and in rotten stumps and logs. Other forms are obtained from flowers, from dead animals, from fungi, in decaying fruits, in seeds and nuts, and under stones, chips, and other rubbish. Frequently many cocoons and chrysalids can be found attached to fences and to the sides of buildings, and many interesting nests occur attached beneath eaves and to the lower surface of the roofs of barns and other buildings.

III. HOW TO COLLECT INSECTS.

There are ways, to be described later, by which large numbers of specimens are easily obtained. But

in these wholesale modes of collecting comparatively little is learned regarding the species collected. On this account careful searching for specimens should be placed first among the methods of collecting. The eye should be trained to detect insects in their natural haunts without disturbing them; then something can be learned of the habits of the species before taking specimens.

By carefully peering into herbage or among the foliage of shrubs and trees many insects can be observed and many lessons learned; other localities in which insects abound are indicated in the preceding section of this chapter.

This looking among herbage, in trees and shrubs, and under stones in the beds of streams, is the simpler part of searching. The more difficult part is to train the eyes to be quick in recognizing the indications of the presence of concealed insects. A dead or dying twig will suggest a search for a borer; the premature turning yellow of the foliage of a branch will suggest a similar cause; the sudden wilting or drooping of isolated plants is generally caused by insects either at the root or in the stalk. A rolled or spotted leaf should be examined and the cause ascertained. In a word, the eyes should be trained to be quick in observing anything abnormal in the appearance of plants; and the mind, to be quick to seek the cause.

THE USE OF NETS.—Much of the success of the collector will depend upon his skill in the use of his net. The deliberate way in which one often sees a net swung would indicate that the collector believes that the insects are waiting to be caught. The small returns, however, which result from this mode of

collecting serve to dispel such belief. The net should be swung so quickly that the insects have not time to escape. In collecting butterflies, dragon-flies, and other swiftly flying insects, it is usually better to wait till the insect alights before attempting to catch it.

For general collecting the most important mode of using the net is that commonly known as sweeping. Larger returns, both as regards the number of species and of specimens, can be obtained in this way than in any other. In order to sweep, the collector grasps his net handle eighteen or twenty inches above the ring, and with a quick motion back and forth in front of him as he walks through the grass or other herbage, sweeps the insects from it into his net. Of course, the net must be turned at the end of each stroke, and must be kept in rapid motion, so that the insects can not escape from it. After sweeping a greater or less distance, depending upon the abundance of specimens, the net is examined, the desirable specimens secured, and the others allowed to escape.

Another method of using a net is to beat from beneath the foliage of shrubs and trees; in this way many specimens can be jarred into the net.

In using a net in water it should be moved back and forth as rapidly as possible, care being taken to beat or sweep any plants growing on the bottom of the pond or stream. Sometimes many specimens can be obtained by sweeping into the net leaves and other rubbish from the bottom of a pond, and bringing them to the shore and looking them over carefully.

In swiftly flowing streams an excellent way to collect is to stand where the water flows swiftest,

holding the net in a vertical position between the feet, and overturning the stones in the bed of the stream in front of the net with a hoe or garden rake. If the current is swift enough many of the insects that live beneath such stones will be swept into the net.

SUGARING.—The method of collecting insects known among entomologists as sugaring is one of the most important to the collector of night-flying moths. Other insects can be taken in this way, but not in so great numbers as moths. A paste is made of sugar and water. Unrefined sugar is the best for this purpose, as it has a stronger odor than white sugar. The paste should be thin enough to be used with a brush, but not so thin that it will flow from the objects to which it is applied. This paste is applied immediately after sunset to the trunks of trees, to fences, and to other suitable objects. In each case a patch about two inches wide and several inches long is made. After dark these baits are visited by the collector, who carries a lantern and several cyanide bottles. One bottle is needed for storing the specimens after they have become quiet, and several bottles for collecting. Some collectors use a dark lantern, but an ordinary lantern will serve the purpose. This should be hung on the left arm, leaving both hands free to manipulate the collecting bottle.

If a patch of sugar be approached cautiously, usually the light can be directed upon it without disturbing the moths that are there feeding. If a specimen is seen that is desired, the cork can be removed from the collecting bottle with the left hand and the bottle placed over the specimen. The insect will

usually fly into the bottom part of the bottle; if it does not, a slight lateral movement of the bottle will cause it to do so. The bottle should then be brought into a vertical position with the mouth directed upward, and quickly carried to the cork which is held in the left hand.

The specimens collected should be left in a cyanide bottle until the following morning. Then there will be no danger of the resuscitation of any of them. Warm dark nights when there is but little or no wind are the best for sugaring.

COLLECTING AT LIGHTS.—Very many insects are attracted to lights, and at such times are easily caught. When electric street lamps can be reached they afford the most prolific fields for the collector. A study lamp placed at an open window on a summer evening, although less prolific than the more conspicuous street lamps, often yields good returns.

CHAPTER II.

THE PRESERVATION OF SPECIMENS.

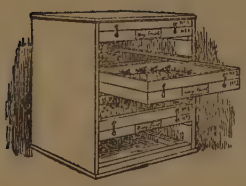

FIG. 258.

THERE are two ways of preserving entomological specimens: they may be either pinned and dried, or they may be placed in a preservative fluid. The method chosen will depend upon the nature of the specimen and the use to which it is to be put. As a rule, any specimen that will preserve its form when dried is pinned. Thus entomologists usually pin the adults of nearly all insects, specimens of nests, infested twigs, mined or rolled leaves, and other similar objects. On the other hand, the immature forms of all insects, and such adults as have soft bodies that will shrivel upon drying, are usually placed in alcohol. Millipedes, centipedes, mites, spiders, and other forms allied to these are also preserved in alcohol. Some insects, on account of their minute size, are mounted as microscopic objects in Canada balsam upon glass slips, as described later.

In case specimens are desired for anatomical study, they are preserved in alcohol or some other fluid, whether the body be soft or not; and certain

hard-bodied insects, as beetles, are often stored in alcohol and pinned later. But many insects, as flies and other hairy forms, are greatly injured by being placed in a fluid, the hairs being matted so that when the insect is pinned it presents an unnatural appearance.

INSECT PINS.—For pinning insects a special kind of pin is ordinarily used—one made of slender wire—so that the specimens are mutilated as little as possible. These can be procured of any dealer in entomological supplies; a list of such dealers is given on page 340.

There are several styles of insect pins, but all of those in general use can be classed under two heads—the English and the German. The English pins are short, so that an insect when pinned is close to the bottom of the cabinet, while the German pins are long, so that the pinned insect is held free from the bottom of the cabinet. By the use of the latter the danger of breaking off the legs from specimens, when they are changed from one place in the cabinet to another, is greatly lessened. Without entering into any further discussion as to the relative merits of the two kinds of pins, it can be said that it would be unwise for an American collector to use any but the German pins, for, as nearly all American entomologists use this style, it would be difficult for a collector using short pins to make exchanges in this country.

Insect pins are made of different sizes of wire and numbered accordingly, but the numbers used by the different makers do not correspond with each other. Below is given the names of the three kinds of Ger-

man pins now advertised for sale in this country, with a list of the sizes of each. Fig. 259 represents Kläger pins:—

FIG. 259.

Kläger: 00, 0, *1*, 2, [*3*], 4, *5*, 6, *7*, 8, 9, 10. Length, $1\frac{3}{8}$ inch.

(Karlsbad) Carlesbader: 0, 1, *2*, 3, 4, [*5*], 6, *7*, *8*, 9, 10. Length, $1\frac{1}{2}$ inch.

Schlüter: 00, *0*, 1, 2, [*3*], 4, 5, *6*, *7*, 8, 9. Length, $1\frac{5}{8}$ inch.

The numbers printed in italics indicate in each case the sizes that will be found most generally useful. If only a single size is purchased, select that in brackets.

A convenient way of storing insect pins is in a block of the form shown in Fig. 260. The holes in the block are about three fourths as deep as the pins are long, so that the heads of the pins project from them. Several holes are made in the block in order that each size of pin can be kept separate.

If for any reason it is impracticable for the pupil to procure insect pins, ordinary pins, or the smaller sizes of the black pins, commonly called mourning pins, can be used. As a rule, the mourning pins have better points than the common brass pins, and are to be preferred on this account, especially when cork or pith is not used in the insect cases. If possible, however, insect pins should be used. Ordinary pins are made of too large wire for pinning insects, and specimens pinned with such pins are rarely suitable for a permanent collection, although

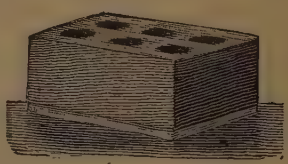
FIG. 260.—Block for pins.

they may serve very well the purposes of a temporary study.

THE PINNING OF SPECIMENS.—The appearance of a collection of insects depends greatly upon the care taken in pinning the specimens. Nearly all insects should be pinned through the middle of the thorax. Many bugs (Hemiptera) are best pinned through the scutellum (Fig. 261), and beetles are pinned through the right wing-cover at about one fourth its length from the base (Fig. 262). About one fourth of the length of the pin should be allowed to project above the specimen; uniformity in this respect will add greatly to the neatness of the appearance of the collection.

FIG. 261.

FIG. 262.

A convenient device for securing uniformity is what may be termed a pinning block. This is made from strips of wood which are one fourth as thick as the pins are long, and which are fastened together as shown in Fig. 263. A hole just large enough to allow the passage of the head of an insect pin is bored through the center of each of the steps of the block. In pinning an insect the pin is pushed through the insect so that less than one fourth of its length projects above it, and then the insect is pushed back into place by in-

FIG. 263.—A pinning block.

serting the head of the pin in the hole in the lower step of the block. This step and the second are used in spacing labels, and the third is used in fixing the height of insects mounted on cardboard points.

Insects that are too small to be pinned, but not so small that they need to be mounted as microscopic objects, are gummed to the points of narrow and pointed pieces of cardboard, which are mounted on pins (Fig. 264). Another way is to impale the insect on the point of a fine pin, inserting the pin into the lower side of the thorax, and then, after cutting away the head and the larger part of the pin, to mount what is left in a narrow strip of firm blotting paper, which in turn is mounted on a large pin (Fig. 265). If suitable cardboard can be obtained for this purpose it is better than blotting paper, but ordinary cardboard is split by the pins. Still another way of mounting small insects is to impale them on the point of a bent pin which is fastened to another pin, as shown in Fig. 266. In preparing these pins the fine one is wound about the coarser one a short distance from the point of the latter, where it is somewhat tapered, the two being held together with pliers; then the head is cut off from the small pin, and it is shoved up toward the head of the coarse one. If care has been taken to wind the fine pin closely about the larger one, it will fit the latter tightly when pushed into the proper position.

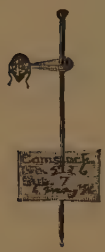

FIG. 264.

FIG. 265.

FIG. 266.

In pinning leaves a small piece of cardboard should be placed on each side of the leaf and the pin pushed through these. This will hold the specimen firmly in place.

PINNING FORCEPS.—In handling pinned specimens pinning forceps are desirable, as by their use there is

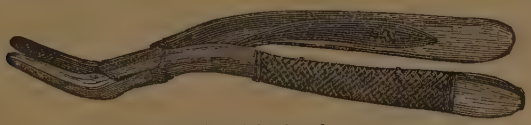

FIG. 267.—Pinning forceps.

much less danger of bending the pins when pushing them into cork. Several styles of pinning forceps are for sale by dealers; that used by the writer is shown in Fig. 267. As these forceps are quite expensive, comparatively few pupils will care to buy them. A good substitute for them are the "flat-nosed" pliers, which can be obtained at any hardware store. By means of these a delicate pin can be grasped firmly near the point and pushed into soft wood without bending it.

FIG. 268.—Pliers.

These pliers are somewhat more convenient to use if one corner be ground off, as shown in Fig. 268.

In transferring specimens that are pinned with slender pins take hold of the head of the pin with the thumb and forefinger of the left hand, and then seize the pin near the point with the pliers. Do all the pushing or pulling with the pliers, but keep the pin from tipping sidewise with the left hand.

In this way there is but little danger of bending the pin.

PRESERVATIVE FLUIDS.—The most important of the preservative fluids is alcohol, and, except for special purposes, no other is needed. The alcohol should be of the full strength of ordinary commercial alcohol—i. e., ninety-five per cent. It should be noted, however, that many soft-bodied insects, especially larvæ, shrivel if put directly into strong alcohol; with these it is necessary to remove the water from the body gradually. This can be done by placing the specimens in alcohol of different strengths successively, using at first fifty per cent alcohol. This can be easily prepared by half filling the bottle with strong alcohol, then nearly filling it with water, and shaking it a few times. The specimens should not be left more than five or six hours in this; they should then be transferred to seventy-five per cent alcohol, prepared in a similar way. They may be left in this for one day, and then transferred to strong alcohol for permanent preservation.

Certain colorless or white grubs and maggots are apt to turn black when preserved in alcohol. This can be prevented by first dipping them in boiling water for a few seconds, after which they should be placed in alcohol as described above.

MOUNTING MICROSCOPIC OBJECTS.—Insects that are too minute to be pinned or satisfactorily mounted on cardboard points are usually mounted in Canada balsam on a glass slide, and covered with a very thin sheet of glass. The slides, balsam, and cover-glasses can be obtained of any dealer in optical apparatus.

In most cases it is necessary to remove the water

from the body of the insect before mounting it; this is done by placing the specimen in alcohol. If the insect is hard so that there is no danger of shriveling, it may be placed in strong alcohol at once, and then mounted after a few hours. Insects with soft bodies should be hardened gradually by being placed successively in fifty per cent, seventy-five per cent, and ninety-five per cent alcohol, as described in the preceding section.

When the specimen is hardened by the alcohol, place it in a watch glass containing a small quantity of oil of cloves, and leave it for a few minutes; this is to remove the alcohol and render the object more clear. Then put the object on the slide, cover it with balsam, and place a cover-glass over the imbedded object. In the course of a few days the balsam will become hard, so that there will be little danger of injury to the specimen by handling the slide.

INFLATING LARVÆ.—The fact that the appearance of many larvæ is greatly altered by preserving them in alcohol leads many entomologists to remove the viscera from such larvæ, especially caterpillars, and inflate and dry the skins. The process is somewhat difficult and disagreeable to perform, but if it is well done very beautiful specimens are obtained, which preserve the form and color of the larvæ much better than those prepared in any other way.

The method of preparation is as follows:—Kill the larva by leaving it for a time in a cyanide bottle. Insert the point of a pin into the posterior end of the alimentary canal, and, by moving it about, break off the hind end of the intestine from its attachment

to the end of the body. Lay the specimen on a sheet of blotting paper, and, placing a lead pencil across it just back of its head, press out the viscera by rolling the pencil toward the hind end of the larva. During this operation move the specimen about on the blotting paper so that the skin will be kept dry. When the contents of the body has been pressed out, insert a straw or a glass tube drawn to a point at the tip in the opening at the hind end, and inflate the skin. If a straw is used, the skin can be fastened to it by thrusting a fine insect pin through it and the straw near the hind end of the specimen. When a glass tube is used, first insert the tube, then remove it carefully so as to leave the opening expanded; heat the point of the tube in the flame of a lamp, and insert it in the opening again. If this is done properly the seared edges of the opening will adhere firmly to the point of the tube. If the opening is not perfectly closed it can be sealed with a drop of glue.

FIG. 269.—An oven.

Inflate the skin, and hold it while inflated in a hot place to dry. The skin can be dried by holding it near to the side of the chimney of a lighted lamp. A more convenient way is to dry it in a little oven, made by laying a large lamp chimney across a tray of sand over a lamp (Fig. 269). If the glass tube be cut in two, and a section of rubber tubing inserted between the two pieces, it will be much more convenient to use. In drying the

skin great care should be taken not to heat it too much so as to destroy the colors.

When the skin is dry, remove it from the tube and mount it on a piece of covered copper wire, which has been bent about a small piece of cork through which an insect pin is pushed, as shown in Fig. 270. The two ends of the wire are inserted in the opening from which the glass tube has been removed, a drop of glue having been previously put on each of the ends (Fig. 271).

FIG. 270.—Wire for mounting skin of larva.

SPREADING INSECTS.—With many insects it is desirable to spread the wings at right angles to the length of the body. Not only do the specimens appear better when prepared this way, but such preparation is necessary in order to see the markings and structure of the wings. This is especially true in the case of butterflies and moths, which are usually spread before being placed in a permanent collection.

FIG. 271.—A mounted inflated skin.

For spreading insects a device known as a spreading board is used. This consists of two strips of wood fastened a short distance apart, so as to leave a groove for the body of the insect, and upon which the wings are fastened in position and left until the insect is dry (Fig. 272). A narrow strip of cork is tacked to the lower side of the two strips of wood; this closes the groove below, and serves as a support for the

pin upon which the insect is pinned. Another strip of wood is fastened to the lower side of the cleats to which the two strips are nailed. This serves as a bottom, and protects the points of the pins which project through the piece of cork.

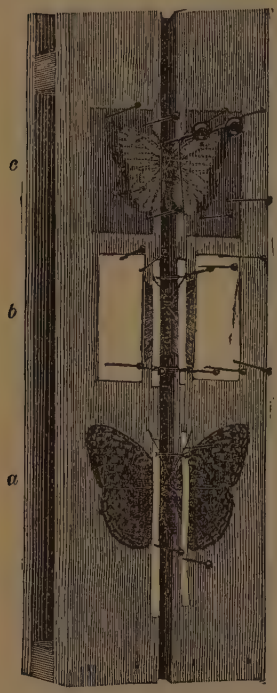

FIG. 272.—A spreading board.

In spreading a specimen a narrow piece of paper is used on each side to hold the wings in place till they are properly arranged (Fig. 272, *a*). The wings are moved into position by slipping them forward or backward under the slips of paper, using for this purpose a fine pin, which is inserted near a strong vein of the wing. When the wings are properly arranged their entire surface is covered with wider strips of paper (Fig. 272, *b*). The specimens are left on the boards till they are dry. This usually requires two or three days. Large, stout-bodied moths should be left on the boards longer.

For pinning the sheets of paper over the wings the sharp-pointed "mourning pins" are much better than the ordinary brass pins, and thin sheets of mica are often used instead of sheets of paper.

A device which may be known as a spreading pin is more convenient than the narrow strip of paper

for holding the wings down while they are being arranged. This is made of a large, sharp-pointed pin (usually a black pin) and a piece of wire (Fig. 273). Fig. 272, *c*, illustrates the way in which these spreading pins are used. Only two of these are needed, as they are removed after the broad strips of paper or mica are pinned over the wings.

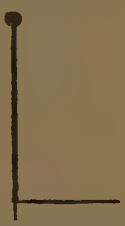

FIG. 273.—A spreading pin.

No rule as to the position in which the wings should be placed can be made that will apply to all specimens. But usually in spreading moths the fore wings are brought so far forward that the hind edges (the inner margins) of the two wings form a straight line across the insect at right angles to the direction of the body, and the hind wings are brought forward so that their front edges (the costal margins) are nearly covered by the fore wings. Great care should be taken to have the wings of the two sides in similar positions.

RELAXING INSECTS.—It is often desirable to spread insects which have become dry; this is especially the case where butterflies are put into envelopes when collected, or where more moths are collected and pinned than can be spread at once. Such specimens can be spread at any time later by first relaxing them. To do this partly fill a vessel with sand and saturate the sand with water; lay the specimens to be relaxed upon a piece of paper spread over this sand, and tightly close the vessel. If a damp towel be spread over the top of the vessel before the cover is put on, the air in the vessel will be more surely kept moist. After the specimens are left for a time—from one to three days—in this moist atmosphere,

they can be spread as easily as when fresh. Care must be taken not to leave the specimens in the relaxing jar too long lest they become moldy. A few drops of carbolic acid poured upon the sand will tend to prevent the growth of mold.

INSECT CASES.—Cases or boxes are needed in which to store specimens when pinned. For temporary use, and especially when it is desirable to avoid all unnecessary expense, empty cigar-boxes can be procured for this purpose. The shallow boxes—those made to hold fifty cigars—are best.

Unfortunately it is impracticable to keep collections of insects permanently in cigar-boxes, for there is a small beetle—the museum pest—which is sure to destroy the specimens if they are not kept in cases with tightly fitting covers. Cigar-boxes will serve the needs of a class while they are carrying on the work; but if the teacher or any of the pupils desire to make a permanent collection, insect cases should be procured. There are many styles of these in use; that described below will be found serviceable and inexpensive, and can be made by any skillful carpenter. It is made as follows:—

The lumber should be basswood or some other nonresinous wood that will not split too easily. Pine is not suitable for this purpose on account of the resin that will exude and injure the specimens. Cut from a board, half an inch in thickness, two strips. One of these should be an inch and a quarter, the other an inch and three quarters wide. Match these together with a tongue and groove three sixteenths of an inch deep, making the groove in the narrower piece. On one side of the narrower piece near the

edge farthest from this groove make another groove fitted to receive a piece of glass, which is to form the top of the case; and on the same side of the wider piece at the edge farthest from the tongue cut a rabbet three eighths of an inch deep; this is to receive the board that is to form the bottom of the case. Fig. 274 represents a cross section of the strips of wood thus prepared, and will serve as a working drawing for the carpenter or cabinet maker.

From these strips the sides of the case are to be made. The tongue and groove should fit snugly, so that pests can not enter the

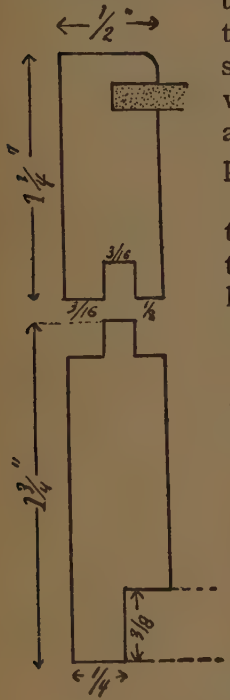

FIG. 274.

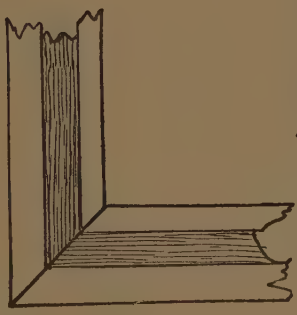

FIG. 275.

FIG. 276.

case when it is closed, and the corners of the case should be very carefully mitered (Fig. 275).

The corners should be both glued and nailed. As soon as the case is put together, and before the glue hardens, the top and bottom should be slightly sepa-

rated so that they shall not be glued together (Fig. 276). If a number is put near one corner on both the cover and the lower part of the box (Fig. 277) it will be easy to determine how the case should be put together after being opened, and thus insure a fit of the two parts. This will also obviate the danger of putting the wrong cover on a case when several of them have been opened at once.

FIG. 277.—An insect case.

The bottom should be made of well-seasoned, soft, nonresinous wood. If the wood is not well seasoned it will shrink and make a crack through which pests will enter. It should be soft so that pins can be easily inserted in it if it is not lined with cork, and nonresinous, as resinous wood will injuriously affect the specimens, and is liable to become unsightly from the exudation of resin. For this reason pine is unsuitable, but basswood is excellent.

It is important that the cases be made of uniform size, so that they may be stored as drawers in a cabinet, or between two upright boards upon which cleats have been nailed three inches apart (Fig. 278). A convenient size is twelve inches and a half by fifteen inches and a half. This admits of the use of glass which measures twelve inches by fifteen inches, a common size of window glass. This is a smaller size than is ordinarily used by those having large collections of insects. But cases of this size will be more convenient for young pupils to handle than larger ones. A larger case is described below as the *college insect case.*

Hooks are usually put on insect cases, as shown in Fig. 277, but they are hardly necessary on small cases if they are made so that the covers fit tightly.

Insect cases are usually left the natural color of the wood on the outside and painted white on the inside. Ordinary oil paint is not suitable for this, as it will turn yellow when kept in the dark. The best paint for this purpose is made of zinc-white and glue. Care should be taken to get the best quality of zinc-white—that which is free from lumps—otherwise a smooth paint can not be made.

In making this paint use an ordinary glue-pot. Dissolve one part by weight of glue in five parts of water. Then stir in zinc-white until the mixture is of the consistency of ordinary paint; about five parts by weight of zinc-white will be required. The mixture is heated while being prepared, and is used warm. If any of the mixture is left unused it forms a solid cake; but this can be liquefied by heat and used when desired. This paint dries in a few minutes after being applied, and will remain permanently a beautiful, clear white.

It is very desirable, if practicable, to have the cases lined with cork. Sheet-cork is kept by the dealers in entomological supplies for this purpose, and recently compressed cork, which, when well made, is better than sheet-cork, has come into use. Compressed cork is ground cork mixed with a small amount of glue, compressed into sheets, and covered with paper. As a single sheet of compressed cork will cover the bottom of the case, it presents a neater appearance than sheet-cork. Thick linoleum, a substance made of cork and used for covering

floors, is also a good substitute for sheet-cork. The use of cork largely obviates the danger of injuring the points of delicate pins.

In certain parts of our country, especially in the warmer parts of California, an excellent substitute for cork can be obtained by cutting into thin slices dead flowering stalks of the century plant. The inner part of such stalks is a very soft pith called pita-wood (pronounced pe'tah-wood).

The pith of large cornstalks is even softer than pita-wood, but it is not as convenient to use on account of its smaller size. But the pupils that are unable to procure cases lined with cork or pita-wood should provide themselves with at least one cigar-box, into the bottom of which they have neatly glued a layer of corn pith. The cork, pita-wood, or corn pith can be covered with a sheet of white paper, giving the case a neat appearance.

If only a single box is thus lined with pith, it should be reserved for the specimens that are being studied—that is, those that are taken out frequently.

THE COLLEGE INSECT CASE.—There is a great lack of uniformity in the size and details of form of the insect cases used in the larger museums. The style used in the great museums at Berlin, Germany, and at Cambridge in this country differs from the one described above in size, the outside dimensions being sixteen inches by nineteen inches by three inches, and in construction, the corners being both dovetailed and mitered, otherwise the two cases are the same. The case used by the writer differs from that used at Berlin and Cambridge only in having the bottom made of glass as well as the top.

The most essential feature of an insect case is that it shall be tight so that museum pests can not enter. In the more common insect cases the bottoms are of wood; but it is extremely difficult

to keep such bottoms from swelling and shrinking with variations in the moisture of the atmosphere. The result is that cases with wooden bottoms are very liable to have cracks in them which will give the museum pests a chance to enter. With the ordinary method of lining insect cases with cork the wooden bottoms admit of the cork being easily fastened in place with tacks; but with the method of arranging insects upon blocks described below there is no occasion for fastening anything to the bottom of the case. Hence glass can be used as well as wood, and with glass for both top and bottom a case can be easily made which shall remain as tight as when new.

THE BLOCK SYSTEM OF ARRANGING COLLECTIONS.—The ordinary way of arranging entomological collections is to pin the specimens into cork fastened to the bottoms of the cases, and this method will probably be found most practicable for the greater number of teachers that use this book; but where a large and rapidly growing collection is to be cared for, the block system of arranging collections, devised by the writer, will be found much more convenient.

Under the old system, a very large proportion of the time of a curator of a rapidly growing collection is devoted to the rearrangement of his collection, to simply removing pinned specimens from one place in a cork-lined case and putting them into another. This not only consumes much time, but results in the breaking of many specimens. Where the block system is used this loss of time and breakage of specimens is reduced to a minimum.

The fundamental idea of the block system is to fasten upon a small block each series of specimens illustrating a single species. A standard size of block is adopted for what may be termed the unit block; other blocks which are multiples or fractions of this size are also used. When it is necessary to rearrange the collection the relative positions of the blocks can be easily and rapidly changed without danger of breaking the specimens.

The blocks are made of soft nonresinous wood and are painted on the upper side with the zinc-white and glue mixture described above. The pins are inserted and removed with pinning forceps or pliers. It is desirable to have a few blocks made of compressed cork or of wood with sheet-cork or linoleum tacked to them for the specimens that are being studied or are not yet classified. When

specimens are ready to be put in a permanent place they are transferred to the wooden blocks; after this it is seldom necessary to remove the pins from the wood.

Where the block system is used it is very important that the insect cases be of uniform size, so that the blocks shall fit well. This can be assured by having an iron frame over which each case is fitted when made. The corners should be cut from this frame so as to make room for the glue that is pressed out from the corners of the case by the clamps that are used in making the case (Fig. 278).

FIG. 278.—Iron frame for mold for cases.

The blocks also should be of uniform sizes. This is most easily attained where they are cut by machinery, and, too, they are much cheaper when made in this way. Those used by the writer are made by a manufacturer of bee-keepers' supplies, and cost unpainted three dollars per thousand.

The blocks are all one third inch in thickness and $4\frac{31}{64}$ inches in length. This admits of there being four columns of blocks in each case.* The variation in size is attained by having the blocks of differing widths. There is given below a list of the widths of blocks used in the entomological collections under the charge of the writer.

BLOCKS FOR MOUNTING INSECTS.

Name of size.	Dimensions in inches.	Remarks.
Double	$4\frac{31}{64} \times 7\frac{1}{2} \times \frac{1}{8}$	Used for series illustrating the transformations or habits of a species.
One and one half	" $5\frac{5}{8}$ "	
Unit	" $3\frac{3}{4}$ "	
Two thirds	" $2\frac{1}{2}$ "	Used for large insects as Lepidoptera and large Orthoptera.
One half	" $1\frac{7}{8}$ "	
One third	" $1\frac{1}{4}$ "	
One fourth	" $\frac{15}{16}$ "	For small insects.
One eighth	" $\frac{15}{32}$ "	For generic and family labels.
One sixth	" $\frac{5}{8}$ "	For filling out columns; only a few of these are needed.
One twelfth	" $\frac{5}{16}$ "	

* The outside dimensions of the case are sixteen inches by nineteen inches. As the wooden sides are half an inch thick, the case measures

The blocks should be made so that the grain of the wood extends along the longer dimension of the block, i. e., from top to bottom in the first two sizes, and from left to right in all others.

BENT-NECKED VIALS.—It is necessary to preserve many specimens in alcohol, and it is very desirable that such specimens should be mounted on blocks so as to be placed with other specimens illustrating the same species. The use of the ordinary vials or glass tubes for this is attended with serious difficulties. It is almost impossible to prevent the leakage of the alcohol and the consequent destruction of the specimens. In addition to this the curved surface of a vial will make the contained specimen appear very different from what it is. A long slender larva will appear much thicker than it is, while its length will not be magnified.

FIG. 279.—A bent-necked vial.

To meet these difficulties the writer has had vials made of the form represented in Fig. 279. The bend in the neck prevents the rapid leakage of alcohol, and the plain sides the magnification of one diameter of the contained specimens. Two sizes of these vials are manufactured—one containing one half ounce, the other two ounces. They can be obtained of Messrs. Whitall, Tatum & Co., New York.

To fix one of these vials to a block a white card is fastened to its lower side with liquid glue (the acetic acid and alcohol solution).

FIG. 280.—Clips for slides on a block.

FIG. 281.

The card is then trimmed close to the sides of the vial, but is allowed to project a short distance beyond each end; then the card is fastened at each end to the block with ribbon pins.

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on the inside fifteen inches by eighteen inches. This would admit of four columns of blocks, each block being four inches and a half long; but n order that the blocks may be easily removed from the case they are ade a little shorter than this.

CLIPS FOR SLIDES.—The glass slides upon which microscopic objects are mounted are fastened to blocks by means of clips which are made from wire (Figs. 280 and 281).

DESTRUCTION OF MUSEUM PESTS.—Even when specimens are kept in tight cases, it often happens that the museum pest finds its way into a case and attacks the specimens. The presence of this tormentor is indicated by a fine dust that falls to the bottom of the case from the infested specimen. All of the cases in a collection should be searched once a month for this indication of the presence of pests. If a case is found to be infested, the pests can be destroyed by pouring a tablespoonful of carbon bisulphide in one corner of the case and tightly closing the case. This substance evaporates rapidly and will destroy the pests without injuring the specimens. It can be obtained of any druggist.

If it is necessary to store away a collection for more than one month, a naphtha cone should be put in each case and strips of paper pasted over the crack between the top and bottom. Naphtha cones can be obtained of dealers in entomological supplies.

MOLD.—In certain regions where the climate is moist specimens are very liable to become covered with mold. The best method of preventing this is to keep a small quantity of carbolic acid in the cases.

CHAPTER III.

ON LABELING SPECIMENS AND TAKING NOTES.

In making a collection of insects, the specimens should be carefully labeled so that it will be possible at any time to tell when and where each one was collected; and if observations are made regarding the insects, these should be recorded in such a way that there can be no doubt regarding the specimens to which they refer. The collector, therefore, should adopt at the outset a definite system of labeling specimens and of taking notes.

It is very important that the system adopted should be a simple one, one that can be easily carried out; for if too much labor is involved there will be great danger that it will not be done.

I. ON LABELING SPECIMENS.

Unnumbered Specimens.—The number of specimens which a collector of insects must handle is so great that it is impracticable to give each specimen a number referring to a catalogue or a note-book, as is customary in collecting larger animals. Entomologists, therefore, when they wish merely to record the locality and date of capture make use of small labels which are placed on the pins below the specimens.

These labels may be either printed or written or partly printed, and with blank spaces to be filled out with a pen. Fig. 282 is a copy of a sheet of labels of the latter kind. With a label of this kind it is only necessary to write a figure indicating the day of the month on which the specimen was collected. It costs but little to have labels like these printed; and they save much labor, and add greatly to the neatness of the collection.

Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.
Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.
Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.
Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.
Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.
Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.	Ithaca, N. Y. Aug. '96.

FIG. 282.—Locality and date labels.

In getting labels of this kind, tell the printer not to space the labels, but to set them solid, so that it will not be necessary to trim them after they are cut apart. The smaller the labels are the better they appear.

In writing labels it is best to use India ink, as the ordinary writing inks fade in the course of a few years if exposed to light. In writing dates use the ordinary abbreviations for the months instead of numerals, as is sometimes done. For when numerals are used there is danger of ambiguity; 6, 9, '96 may mean either 6 Sept., '96, or June 9, '96.

In the case of bottles of alcoholic specimens pin a label to the stopper, for convenience of reading, and put a duplicate within the bottle to prevent the occurrence of mistakes from an exchange of stoppers.

Sometimes in addition to the label indicating the locality and date of capture, it is desirable to add one indicating the conditions of capture, as at sugar, at

electric light, or in the twilight. We have sheets of labels printed for this purpose (Fig. 283).

When more than one label is used they are spaced on the pin so that each can be read.

Sugar. Light. Twilight.
Sugar. Light. Twilight.
Sugar. Light. Twilight.
Sugar. Light. Twilight.
Sugar. Light. Twilight.
Sugar. Light. Twilight.

FIG. 283.—Labels indicating conditions of capture.

NUMBERED SPECIES. — In the study of life histories it is often necessary to record more information than can be placed upon labels. In such cases the specimens and notes should be given corresponding numbers. Even in this case it is not best to give each specimen a distinct number; a much simpler way is to give all specimens of each species the same number.

Suppose, for example, that the first species studied is the apple-tree tent-caterpillar. In this case all the specimens of this species should be labeled No. 1, and all notes on this species should have the same number. The next species studied should be numbered No. 2, and so on.

The locality and date labels, already described, can be used in connection with the numbered labels; there is no objection to putting two or three labels on a specimen if each records additional information.

Sometimes it is desirable to make notes regarding a particular specimen, which shows some individual peculiarity or was collected under peculiar conditions. In such a case use is made of a subnumber, which is written on the label below the number referring to the species.

Fig. 284 represents a sheet of labels such as we use for our numbered species. Cornell U. is printed

on each label to avoid the danger of mistakes occurring in case exchanges are made with collectors using a similar system. Each of our students using this system has his name printed in the corresponding place on his labels. The blank space after the abbreviation Sub. is used only when it is necessary to give a subnumber, as indicated above. A narrow blank space is left below the place for the subnumber in which a date may be written.

Cornell U. No. Sub.	Cornell U. No. Sub.	Cornell U. No. Sub.
Cornell U. No. Sub.	Cornell U. No. Sub.	Cornell U. No. Sub.
Cornell U. No. Sub.	Cornell U. No. Sub.	Cornell U. No. Sub.
Cornell U. No. Sub.	Cornell U. No. Sub.	Cornell U. No. Sub.

FIG. 284.—Labels for numbered species.

NUMBERED LOTS OF SPECIMENS.—The method of labeling specimens described above will be sufficient for the needs of those whose collections are small. The following suggestion is for those having charge of large and rapidly growing collections:—

It often happens that a large number of specimens, not all of the same species, are to be labeled, respecting each of which precisely the same record is to be made. It is my practice to give each lot of specimens of this kind a number, and to place on each specimen a label indicating the lot to which it belongs. In a note-book, kept especially for this purpose, and known as the Lot Book, a full account of each lot is written. By doing this the record is as complete as it would be were each specimen given a number, and a note written for each. Fig. 285 represents a sheet of the labels used for this purpose. The following extracts from the Lot Book of Cornell University will illustrate the application of this system:—

Cornell U. Lot Sub.	Cornell U. Lot Sub.	Cornell U. Lot Sub.
Cornell U. Lot Sub.	Cornell U. Lot Sub.	Cornell U. Lot Sub.
Cornell U. Lot Sub.	Cornell U. Lot Sub.	Cornell U. Lot Sub.
Cornell U. Lot Sub.	Cornell U. Lot Sub.	Cornell U. Lot Sub.

FIG. 285.—Labels for numbered lots of specimens.

LOT 30.—Lepidoptera from Colorado. These were collected and presented to the university by Mr. H. W. Nash. See Letter File I, page 43.

LOT 31.—Coleoptera from Arizona. These were collected by Mr.

H. K. Morrison. They were purchased in February, 1883. See letters.

Lot 45.—A collection of Hemiptera determined by Professor P. R. Uhler during the year 1883. See correspondence in Letter Book I and Letter File I. The subnumbers refer to a list furnished by Professor Uhler, which is in Letter File I, pp. 166–172.

The last extract illustrates a very important use made of lot numbers. In this way it is easy to label each specimen so that its name and the authority for the determination can be easily ascertained. And as the label is a small one placed upon the pin, there is no danger of the specimen and its label becoming separated. These labels are used in addition to the larger labels placed at the head of each series of specimens in a systematic collection.

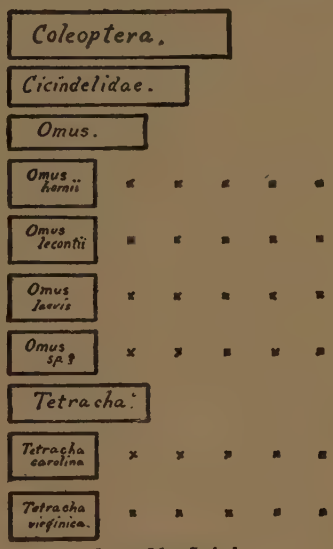

Fig. 286.—Labels.

Blank Forms for Labels. — In arranging specimens in a systematic order in a collection, there should be placed at the head of each group of insects a label bearing the name of the group. These labels are used in addition to those already described, which are always left on the pins or in the bottles as the case may be. The group labels are of larger size than the preceding, and are usually written on blank forms like those shown in Fig. 286, except that it is customary to have the forms printed in red ink; and the forms are twice as long and twice as wide as shown here.

The four sizes are used for the names of orders, families, genera, and species respectively. The method of arrangement of these labels is also shown in Fig. 286, the x's representing the position of the specimens thus labeled.

These figures represent the style of labels ordinarily used in collections. In the case of collections made by young pupils who are beginning the study of insects more extensive labels may be desirable. These should be neatly written on plain paper and a line drawn about each with a pen. See examples in Lessons XVIII and XXV.

II. ON TAKING NOTES.

NOTE-BOOKS AND SLIPS.—There are two distinct systems of keeping notes: By one, the notes are written in a blank book; by the other, they are written on slips of paper, which are afterward arranged according to subjects.

An objection to the use of a note-book arises from the fact that when one begins a series of observations it is impossible to determine how much space is going to be required for the notes on it; and, consequently, it is impracticable to keep together all notes on each subject. By the slip system this is easily done; for this reason, most naturalists write their notes on slips or sheets of paper, and keep them classified in envelopes or covers.

A combination of these two systems meets most perfectly the needs of an entomologist. It is my practice to write notes on general subjects on sheets of paper, which are kept classified in folded sheets of Manilla paper. But for the notes on species of in-

sects both a note-book and loose sheets of paper are used.

The species on which observations are made are numbered, as described on page 317. The note-book is a paged blank book, which is made of ruled quarto paper. There is a single red line about one inch from the left margin of each page. An entire page is devoted to each number; this greatly facilitates the finding of notes. for the number of the notes and that of the page are the same. The space at the left of the red line is reserved for dates and subnumbers. The first line of the notes consist only of the name of the species; if this is not known at the time the notes are begun, the line is left blank and a descriptive title for temporary use is written on the second line.

As already stated, one page of the note-book is reserved for notes on each species. In many cases this page is sufficient; when it is found insufficient, the expression "See notes" is written at the end of the note in the book, and all further notes are written on loose sheets. These are kept in folded sheets of Manilla paper, which are stored in boxes in their numerical sequence.

The use of a note-book in this system is a sure protection against the danger of using the same number twice; and it is the most convenient method of keeping the notes on the large number of species respecting which extended observations are not made; while the supplementary sheets afford all the advantages of the slip system when extended observations are made.

INDICATION OF SEX.—In many insects there are marked external sexual differences, either of size,

form, color, or of shape of appendages. In others it is difficult to determine the sex without dissection. When the sex of a specimen is known it should be indicated on the label. This is commonly done by using the astronomical sign ♂ or ♀, the former indicating the male sex, the latter the female. It will aid the student in distinguishing these signs to remember that ♂ represents the shield and spear of Mars, and ♀ the hand-glass or mirror of Venus. In the case of social insects, as ants, bees, and wasps, the workers are indicated by ☿.

ON TAKING NOTES.—After many years' experience I am sure that nothing more important can be said to the young student regarding the taking of notes than to urge him to take them at the time the observation is made. If you make an observation in the field do not wait till you return to your study to record it, but write an account of what you have seen immediately, and do this, if possible, while observing the fact. Almost invariably the writing of an account of an observation will suggest queries, many of which can be answered at the time the observation is made, but not after the observer has returned to his study.

Even in those cases where it is intended to make a long and serious study of a subject, every phenomenon observed should be noted as soon as seen. Make your record while the occurrence is fresh in your mind, before it loses the charm of novelty and becomes a commonplace. Many an account is very incomplete simply because the writer has become so familiar with certain details that it does not seem to him worth while to record them. The reader will

please bear in mind that I have reference merely to the taking of notes for the observer's personal use; the publication of conclusions based upon hasty, first impressions is not advised. Fill your note-book with descriptions, but digest them carefully, sifting out for publication only those that exhaustive study and repeated observations prove to be valuable. In making observations *be sure you are right and then look again.*

Write your notes in as good style as you can command. It does not pay to be slovenly here, giving no attention to literary form. Remember, however, that the more simple and direct an account is, the better its style.

DESCRIPTIONS OF INSECTS.—One of the best methods of training the powers of observation is by writing descriptions of natural objects; for the preparation of a careful description will lead the describer to see many features that otherwise would not be observed.

The nature of the description will depend greatly on the amount of experience the writer of it has had. The young beginner of Nature study will be expected to mention only the more general features of the object described, while the more advanced student should be able to point out its distinctive characteristics. Thus in describing a butterfly the beginner should note, among other things, that it has six legs, four wings, a pair of horns (antennæ), two large eyes, a coiled tube for sucking, and that the wings are clothed with a dustlike substance. But the more advanced student should not be expected to state any of these facts, except by implication in the statement

that the insect described is a butterfly, for the including of characteristics that are true of all butterflies would be unnecessary, and tend to obscure the importance of the more distinctive features of the species described. He should not attempt to say everything possible about the insect, but should try to discover and state in what respects the butterfly described differs from other butterflies; so that the reader of his description can recognize with as little effort as possible the particular species described.

No detailed rules for describing insects can be easily given; the peculiar characteristics will be found in different organs in different cases. The following are some of the features that should be studied in search for distinguishing characteristics when describing adult insects:—

1. The body as a whole.—The size of the insect; the general color; the color of the more prominent markings; the relative proportions of the head, thorax, and abdomen; the clothing of the body, as scales, hairs, and spines; and any striking peculiarity of the appendages of the body.

2. The head.—The relative size of the head; the details of the color markings of the head; the size and shape of the compound eyes; variations in size of the ocelli in different parts of the compound eyes; the presence or absence of hairs either in or fringing the compound eyes; the number and position of the simple eyes; the insertion of the antennæ; the general form of the antennæ; the clothing of the antennæ; the relative length of the different segments of the antennæ; the form of the labrum; the shape of the mandibles; the structure of the maxillæ and maxillary palpi; and the structure of the labium and labial palpi.

3. The thorax.—Peculiarities in the size and form of the thorax; the details of the markings of the thorax; the structure and coloring of the wings; the structure, clothing, and armature of the legs; and the position of the thoracic spiracles.

4. The abdomen.—The size and general form of the abdomen; the number of visible abdominal segments; the details of the markings of the abdomen; the number and structure of the caudal appendages; and the number and position of the abdominal spiracles.

In preparing a description of a larva the following features should be observed:—

The size and general form of the body; the presence or absence of legs and of prolegs; the number and position of the prolegs when present; in footless larvæ, the presence or absence of a distinct head; the general color of the skin, and the color and pattern of its markings; the nature of the clothing or armature of the body; the colors of the clothing or armature; in "naked" larvæ, the arrangement of the tubercles bearing minute hairs or more conspicuous spines; in hairy larvæ, the arrangement of the hairs, whether scattered evenly over the body or gathered in tufts; if the hairs are tufted, the arrangement of the tufts; the number and position of long pencils of hairs if present; the number and position of the spiracles.

In addition to the above, there are many features characteristic of limited groups of insects which will be learned by the student as he advances in the study of such groups.

CHAPTER IV.

THE BREEDING OF INSECTS.

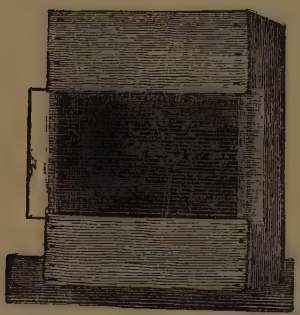

FIG. 287.—A home-made breeding cage.

IN the study of the life histories of insects many facts can be most easily and surely determined by the study of specimens in confinement. It is rarely practicable to watch the development of an individual insect in the field, but with the aid of a breeding cage this is easily done. The use of breeding cages also enables the lover of Nature study to keep constantly at hand where they can be seen daily, or even hourly, examples of the life of the fields and ponds.

In collecting insects for study in confinement it is necessary to note carefully the conditions under which they naturally live, and then to imitate these conditions as closely as possible. If the insects are feeding on a plant, the kind of plant and the part infested should be observed, so that the specimens when confined may be given the proper food. If they live in water, determine whether they will re-

quire running water or can be kept in an ordinary aquarium. And if they are predaceous, the nature of their food should be ascertained, if possible, although many predaceous insects can be fed on raw meat.

Great care should be taken not to injure the specimens when collecting them. Plant-eating species can be carried in tight boxes, in which should be placed a quantity of their food. Air holes in the boxes are not necessary. It is more important that the food be kept from wilting than that there should be fresh air. If aquatic insects are to be collected, large bottles with wide mouths or glass fruit-cans will be convenient for transporting them. If the bottles or cans be only partly filled with water they may be closed tightly for the time occupied by an ordinary field trip.

Breeding Cages.—Several styles of elaborate and expensive breeding cages are in use by professional entomologists, but it seems hardly worth while to describe them here, for equally good results can be obtained with simple and inexpensive cages, which can be made by any handy boy.

A good home-made cage can be built by fitting a pane of glass into one side of an empty soap-box. A board, three or four inches wide, should be fastened below the glass so as to admit of a layer of soil being placed in the lower part of the cage, and the glass can be made to slide, so as to serve as a door (Fig. 287). The glass should fit closely when shut, to prevent the escape of insects.

In rearing caterpillars and other leaf-eating larvæ branches of the food plant should be stuck into bot-

tles or cans which are filled with sand saturated with water. By keeping the sand wet the plants can be kept fresh longer than in water alone, and the danger of the larvæ being drowned is avoided by the use of sand.

Many larvæ when full-grown enter the ground to pass the pupa state; on this account a layer of loose soil should be kept in the bottom of a breeding cage. This soil should not be allowed to become dry, neither should it be soaked with water. If the soil is too dry the pupæ will not mature, or if they do so the wings will not expand fully; if the soil is too damp the pupæ are liable to be drowned or to be killed by mold.

It is often necessary to keep pupæ over winter, for a large proportion of insects pass the winter in the pupa state. Hibernating pupæ may be left in the breeding cages or removed and packed in moss in small boxes. Great care should be taken to keep moist the soil in the breeding cages, or the moss if that be used. The cages or boxes containing the pupæ should be stored in a cool cellar, or in an unheated room, or in a large box placed out of doors where the sun can not strike it. Low temperature is not so much to be feared as great and frequent changes of temperature.

Hibernating pupæ can be kept in a warm room if care be taken to keep them moist, but under such treatment the mature insects are apt to emerge in midwinter.

An excellent breeding cage is represented by Fig. 288. It is made by combining a flower-pot and a lantern-globe. When practicable, the food plant of

Plate XVIII.—CATERPILLARS.

1. A cutworm, *Noctua clandestina.*
2. The Two-lined Prominent, *Seriodonta bilineata;* it feeds on the leaves of oak, elm, and basswood.
3. The same as Fig. 2. A green variety.
4. The Zebra Caterpillar, *Mamestra picta;* it feeds on cabbage and other garden vegetables.
5. The Apple-tree Tent-caterpillar, *Clisiocampa americana.* See page 168.
6. The Tent-caterpillar-of-the-forest, *Clisiocampa disstria.* See page 172.
7. The Well-marked Tussock-moth, *Notolophus definita.* See Plate VIII, Fig. 10, for the adult.
8. The White-marked Tussock-moth, *Notolophus leucostigma.* See page 174; also Plate VIII, Fig. 9.

Plate XVIII

FIG. 288.

FIG. 289.

the insects to be bred is planted in the flower-pot; in other cases a bottle or tin can filled with wet sand is sunk into the soil in the flower-pot, and the stems of the plant are stuck into this wet sand. The top of the lantern-globe is covered with Swiss muslin. These breeding cages are inexpensive, and especially so when the pots and globes are bought in considerable quantities. Fig. 290 represents a modification of this style of breeding cage that is used by the writer. It differs only in that large glass cylinders take the place of the lantern-globes. These cylinders were made especially for us by a manufacturer of glass, and cost from six dollars to eight dollars per dozen, according to size, when made in lots of fifty.

FIG. 290.

When the transformations of small insects or of a small number of larger ones are to be studied, a convenient cage can be made by

combining a large lamp-chimney with a small flower-pot (Fig. 289).

AQUARIA.—For the breeding of aquatic insects aquaria are needed. As the ordinary rectangular aquaria are expensive and are liable to leak, we use glass vessels instead.

Small aquaria can be made of jelly-tumblers, glass finger-bowls, and glass fruit-cans, and larger aquaria, of the form shown in Fig. 291, can be obtained of some dealers. A good substitute for these is what is known as a battery-jar. There are several sizes of these, which can be obtained of most dealers in scientific apparatus.

FIG. 291.

To prepare an aquarium, place in the jar a layer of sand; plant some water plants in this sand, cover the sand with a layer of gravel or small stones, and then add the required amount of water carefully so as not to disturb the plants or to roil the water unduly. The growing plants will keep the water in good condition for aquatic animal life, and render changing of the water unnecessary, if the animals in it live naturally in quiet water. Among the more available plants for use in aquaria are the following :—

Waterweed, *Elodea canadensis.*

Bladderwort, *Utricularia* (several species).

Water-starwort, *Callitriche* (several species).

Watercress, *Nasturtium officinale.*

Stoneworts, *Chara* and *Nitella* (several species of each).

Frog-spittle or water-silk, *Spirogira.*

A small quantity of duckweed, *Lemna* (Fig. 292), placed on the surface of the water adds to the beauty of an aquarium.

FIG. 292.—Duckweed.

When it is necessary to add water to an aquarium on account of loss by evaporation, rain water should be used to prevent an undue accumulation of the mineral matter held in solution in other water.

THE CONSTANT-LEVEL SIPHON.—Certain insects that live in rapidly flowing streams require a constant change of water. Some of these are extremely difficult to breed in confinement, but others can be kept alive easily if placed in an aquarium which is prepared as described above, and through which there is a stream of water constantly flowing.

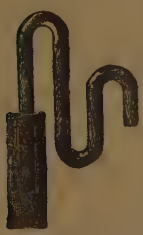

FIG. 293.—Constant-level siphon.

The water can be admitted to the aquarium from a faucet, and the surplus water removed by a device which may be called a constant-level siphon. This is represented in operation in Fig. 291, and separate in Fig. 293.

The siphon can be made of small lead pipe. It differs from an ordinary siphon in being bent up at the outer end (the last bend shown in the figure is

not essential; it is the one preceding that which is referred to here) and in having the inner arm (the

FIG. 294.—Section of a root cage.

one within the aquarium) longer than the outer arm. These two peculiarities prevent the emptying of the

siphon, as air can not enter at either end. If the bore of the siphon is considerably larger than the stream of water flowing into the aquarium, the water in the aquarium will be kept at a constant level, which will be that of the outer end of the siphon.

To prevent the escape of the insects through the siphon, a cylinder of fine wire gauze, closed at each end with a disk of cork, is fitted over the inner end of the siphon (Fig. 293).

THE ROOT CAGE.—For the study of insects that infest the roots of plants, the writer has devised a special form of breeding cage known as the root cage. In its simplest form this cage consists of a

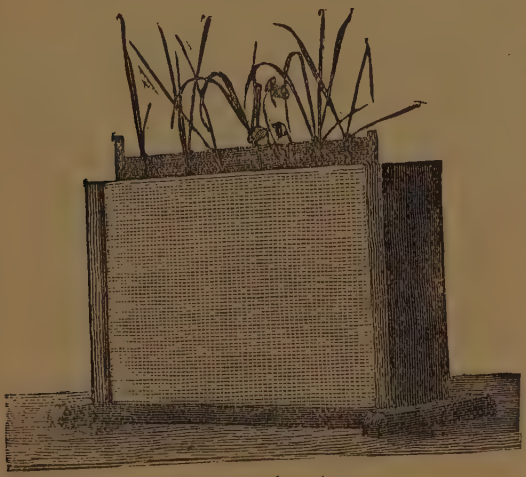

FIG. 295.—A root cage.

frame holding two plates of glass in a vertical position and only a short distance apart. The space between the plates of glass is filled with soil in which

seeds are planted or small plants set. The width of the space between the plates of glass depends on the width of two strips of wood placed between them, one at each end, and should be only wide enough to allow the insects under observation to move freely through the soil. If it is too wide the insects will be able to conceal themselves. Immediately outside of each glass there is a piece of blackened zinc, which slips into grooves in the ends of the cage, and which can be easily removed when it is desired to observe the insects in the soil. Fig. 294 represents a small section of such a cage with the zinc removed.

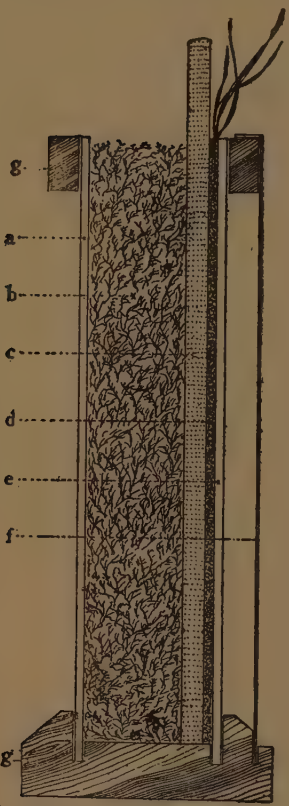

FIG. 296.—A sectional view of a root cage.

In a more expensive form of the cage, which is used in the Insectary of Cornell University (Fig. 295), there is only one plate of glass next to the soil, the place of the other plate of glass being occupied by a porous tile, between which and an outer plate of glass is packed a layer of moss. By wetting the moss sufficient moisture passes through the porous tile to keep the soil in good condition for the growth of the plants in the

soil without unduly wetting the soil. A cross section of this cage is represented by Fig. 296; the parts are as follows:—*a*, plate of glass forming the back of the cage; *b*, space filled with moss; *c*, porous tile; *d*, thin space filled with soil in which seed is sown and the insects to be watched are placed; *e*, plate of glass forming the front of the cage; *f*, a sheet of zinc for darkening the cage—this is removed when observations are to be made; *g g*, sections of the wooden frame of the cage.

FIREFLIES.*

As o'er the face of Evening fair
A shade of twilight came,
Lost sunbeams, tangled in her hair,
Fell into drops of flame.

Charles Henry Lüders.

* From The Dead Nymph and other Poems, by permission of Charles Scribner's Sons.

CHAPTER V.

MISCELLANEOUS LISTS.

I. BOOKS ON INSECTS.

THE literature of entomology is very extensive. Hundreds of books on insects have been printed, and more than twenty-five journals devoted exclusively to this subject are now published. In addition to this, most of the zoölogical journals contain articles on insects.

Nevertheless there is still a lack of the kind of books usually sought for by beginners in this study. There are a few good general text-books on the subject, and a larger number of excellent popular works on the habits of insects, but there does not exist today a fairly complete treatise on the American species of any order of insects. The fact is, the science of entomology is still in its infancy, and a great field is open for the earnest worker.

In the following list there are enumerated those works that are most useful to beginning students. More advanced students should consult The Zoölogical Record in order to ascertain the titles and places of publication of more special treatises. *

* The Zoölogical Record is published annually by the Zoölogical Society of London. Each volume gives a complete list of the works and

GENERAL TEXT-BOOKS.

COMSTOCK, J. H. and A. B.—A Manual for the Study of Insects. Comstock Publishing Company, Ithaca, N. Y., 1895. Price, $3.75 net; postage, 34 cents.

This work contains a series of analytical tables by means of which the family to which any North American insect belongs can be determined. Under the head of each family the characteristics of the family, both as regards structure and habits, are given, and the more common species are described. It is profusely illustrated.

HYATT, ALPHEUS, and ARMS, J. M.—Guides for Science Teaching. No. III. Insecta. D. C. Heath & Co., Boston, 1890. Price, $1.25.

A very useful work for teachers.

PACKARD, A. S.—Guide to the Study of Insects. Henry Holt & Co., New York. Price, $5. (First edition, Salem, 1869.)

PACKARD, A. S.—Entomology for Beginners. Henry Holt & Co., New York, 1888. Price, $1.40.

THE CAMBRIDGE NATURAL HISTORY, VOL. V.—Peripatus, by A. Sedgwick; Myriapods, by F. G. Sinclair; Insects, Part I, by David Sharp. Macmillan & Co., London and New York, 1895. Price, $4.

This, in many respects, is the best text-book on entomology yet published. The beginning student who wishes to study North American insects will find Comstock's Manual better suited to his needs, but this volume of The Cambridge Natural History should

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publications relating to zoölogy in all its branches that have appeared during the year preceding the date of the volume. The first volume was for the year 1864.

be in the library of every advanced student of entomology. Part II of this work, which will treat of the Hemiptera, Lepidoptera, Diptera, and Coleoptera, has not yet (1896) appeared. It is to constitute Vol. VI of the series.

THE STANDARD NATURAL HISTORY.—The title of this work has been changed to The Riverside Natural History.

THE RIVERSIDE NATURAL HISTORY.—Edited by John Sterling Kingsley. Six volumes, royal 8vo. Houghton, Mifflin & Co., Boston and New York. Price, $30, $36, or $42, depending on the binding.

Vol. II of this work treats of the Crustacea and insects. Unfortunately, it can not be purchased separately, and the entire work is too expensive for most students. It is, however, an excellent work of reference for a school library.

HARRIS, T. W.—Insects Injurious to Vegetation. (Flint edition.) Orange Judd Company, New York. Price, plain plates, $4; colored plates, $6.50.

Although this is an old work and consequently somewhat out of date as regards classification, it is one of the best books on insects ever written; it doubtless has done more to stimulate an interest in the study of insects than any other American work. It is magnificently illustrated.

SMITH, JOHN B.—Economic Entomology. J. B. Lippincott & Co., Philadelphia, 1896. Price, $2.50.

This is a very useful text-book intended especially for students in agricultural colleges.

SAUNDERS, WILLIAM.—Insects Injurious to Fruits. J. B. Lippincott & Co., Philadelphia, 1883. Price, $2.

This is a very useful work. The insects discussed are classified according to the plants they infest.

WEED, CLARENCE M.—Insects and Insectides. Orange Judd Company, New York. Revised edition, 1895. Price, $1.50.

RILEY, C. V.—Directions for Collecting and Preserving Insects. Smithsonian Institution, Washington, D. C., 1892. Price, 25 cents.

This is a very complete treatise on the subject named. It also contains a much larger list of writings on insects than that given here.

MORE SPECIAL WORKS.

SCUDDER, S. H.—Brief Guide to the Commoner Butterflies of the Northern United States and Canada. Henry Holt & Co., New York, 1893. Price, $1.25.

FRENCH, G. H.—The Butterflies of the Eastern United States. J. B. Lippincott & Co., Philadelphia, 1886. Price, $2.

LE CONTE and HORN.—Classification of the Coleoptera of North America. Secretary of the American Entomological Society, Philadelphia. Price, $2.50.

WILLISTON, S. W.—Manual of North American Diptera. Second edition, 1896. James T. Hathaway, New Haven, Conn. Price, $2.25.

CRESSON, E. T.—Synopsis of the Families and Genera of the Hymenoptera of America North of Mexico. Secretary of the American Entomological Society, Philadelphia. Price, $3.

MURRY, ANDREW.—Economic Entomology: Aptera. Chapman & Hall, 193 Piccadilly, London. Out of print. To be obtained of dealers in second-hand books.

This work is especially valuable for its discussion of mites.

MIALL, L. C.—The Natural History of Aquatic Insects. Macmillan & Co., London and New York, 1895. Price, $1.75.

BANKS, NATHAN.—A Synopsis, Catalogue, and Bibliography of the Neuropteroid Insects of Temperate North America. (From the Transactions of the American Entomological Society, Vol. XIX.) Secretary of the American Entomological Society, Philadelphia. Price, 50 cents.

CALVERT, PHILIP P.—Catalogue of the Odonata (Dragon-flies) of the Vicinity of Philadelphia, with an introduction to the study of this group of insects. (From the Transactions of the American Entomological Society, Vol. XX.) Secretary of the American Entomological Society, Philadelphia. Price, $1.

ON THE HABITS OF INSECTS.

KIRBY and SPENCE.—An Introduction to Entomology. Seventh edition. One volume, which is a reprint of Vols. I and II of earlier editions. London, 1856.

This work is out of print, and can be obtained only of dealers in second-hand books. But it is to be found in most of the larger public libraries.

There are many other excellent works on the habits of insects, but they can not be enumerated here for lack of space.

II. DEALERS IN ENTOMOLOGICAL SUPPLIES.

Charles C. Riedy, 432 Montgomery Street, San Francisco, Cal.

A. Smith & Sons, 269 Pearl Street, New York, N. Y.
John Akhurst, 78 Ashland Place, Brooklyn, N. Y.
M. Abbott Frazar, 93 Sudbury Street, Boston, Mass.
Entomological Society of Ontario, Victoria Hall, London, Ontario.
Queen & Co., 1010 Chestnut Street, Philadelphia, Pa.
The Bausch & Lomb Optical Company, 515–543 N. St. Paul Street, Rochester, N. Y.

III. DEALERS IN OPTICAL INSTRUMENTS.

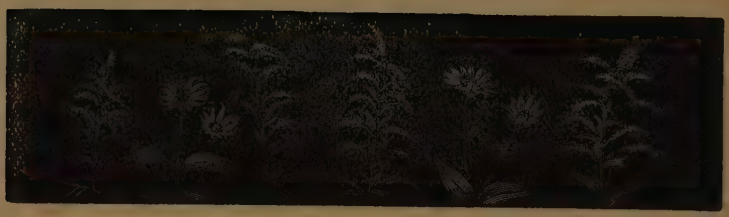
The Bausch & Lomb Optical Company, New York city and Rochester, N. Y.
Eimer & Amend, 205–211 Third Avenue, New York city.
The Franklin Educational Company, Harcourt Street, Boston, Mass.
J. Grunow, 70 W. Thirty-ninth Street, New York.
The Gundlach Optical Company, Rochester, N. Y.
William Krafft, 411 W. Fifty-ninth Street, New York.
The McIntosh Battery and Optical Company, 521–531 Wabash Avenue, Chicago, Ill.
Queen & Co., 1010 Chestnut Street, Philadelphia, Pa.
Richards & Co., 30 E. Eighteenth Street, New York, 108 Lake Street, Chicago, Ill.
Edward Pennock, 3609 Woodland Avenue, Philadelphia, Pa.
Spencer Lens Company, 546 Main Street, Buffalo, N. Y.
Walmsley, Fuller & Co., 134–136 Wabash Avenue, Chicago, Ill.

Williams, Brown & Earle, Tenth and Chestnut Streets, Philadelphia, Pa.

G. S. Woolman, 116 Fulton Street, New York.

J. Zentmayer, 209 S. Eleventh Street, Philadelphia, Pa.

Charles C. Riedy, 432 Montgomery Street, San Francisco, Cal.



INDEX.

Abdomen, 19.
Acrididæ, 72.
Adult, 40.
Agalena nævia, 224.
Agamic, 177.
Aglais milberti, 252.
Alder-blight, 163.
Ambush-bug, 274.
American tortoise-shell, 252.
Andrena, 269.
Andriconia, 247.
Angle-wings, 250.
Anisota oak-worms, 199.
Anosia plexippus, 249.
Antennæ, 12.
Ant-lions, 77.
Ant-nest, 278.
Ants, 85, 178, 275.
Aphididæ, 163.
Aphids, 75, 163, 175.
Aphis-lions, 77, 78, 178, 179.
Apple-tree tent-caterpillar, 168.
Aquaria, 330.
Arachnida, 53, 55.
Arctiidæ, 239.
Arthropoda, 52.
Automeris io, 189.
Back-swimmers, 123, 128.
Bag-worm, 204.
Ballooning spiders, 226.
Basilarchia archippus, 249.
Basilona imperialis, 197.
Bees, 85, 254.
Beetles, 41, 85.
Belostoma, 130.
Bent-necked vials, 313.
Bird-lice, 69.
Bittacus, 79.
Black-flies, 156.
Black swallow-tail, 243.
Blank forms for labels, 319.
Blattidæ, 71.
Blepharoceridæ, 159.
Blister-beetles, 273.
Block system of arranging collections, 311.
Blues, 247.
Book-lice, 68.
Books on insects, 336.
Boreus, 79.
Breathing holes, 19.
Breeding cages, 327.
Breeding of insects, 326.
Bristletails, 63.

Broad-shouldered water-striders, 109.
Brownie-bugs, 219.
Bugs, 75.
Bumblebees, 256.
Butterflies, 80, 82, 239.

Caddice-flies, 79, 151.
Caddice-worms, 79, 148, 151.
Callosamia promethea, 193.
Calocalpa undulata, 200.
Cases, 306.
Caterpillars, 239.
Cattle-tick, 57.
Ceanothus silkworm, 196.
Cecidomyiidæ, 162.
Cecropia-moth, 195.
Cells of the wings, 17.
Centipede, 57.
Cephalothorax, 55.
Cerambycidæ, 215.
Chauliodes, 156.
Chauliognathus, 273.
Chrysopidæ, 179.
Cicada-killer, 270.
Cicadas, 218.
Cicada septendecim, 218.
Cicada tibicen, 218.
Cigar-boxes, 306.
Citheroniidæ, 197.
Citheronia regalis, 199.
Clematis, 30.
Cliff-dwellers, 267.
Clips for slides, 314.
Clisiocampa americana, 172.
Clisiocampa californica, 172.
Clisiocampa constricta, 172.
Clisiocampa disstria, 172.
Cobweb-weavers, 227.
Coccidæ, 277.
Coccinellidæ, 180.
Cockroaches, 70, 71.
Cocoon, 40.
Codlin-moth, 180.
Coleoptera, 41, 43, 85.
Collecting apparatus, 284.
Collecting boxes, 287.
Collecting butterflies, 45.
Collecting moths, 50.
College insect case, 310.
Colorado potato-beetle, 44.
Complete metamorphosis, 35, 38.
Compound eyes, 12.
Compton-tortoise, 253.
Conotrachelus nenuphar, 184.
Coppers, 246.
Corisidæ, 140.
Corrodentia, 68.
Corydalis, 78.
Corydalis cornuta, 155.
Cosmopolitan butterfly, 251.
Coxa, 15.
Crabs, 54.
Crab-spiders, 230.
Crayfishes, 53.
Crescent-spots, 249.
Crickets, 70, 74, 233, 237.
Crustacea, 53.
Culicidæ, 136.
Curculionidæ, 184.
Curculios, 184.
Cyanide bottle, 286.
Cyclops, 54.
Cycnia egle, 241.
Cyllene robiniæ, 273.
Cynipidæ, 212, 214.
Cypris, 54.

Damsel-flies, 65, 89, 93, 98, 140.
Daphnia, 54.
Darning-needles, 89.
Datana ministra, 173.

Dealers in entomological supplies, 340.
Dealers in optical instruments, 341.
Descriptions of insects, 323.
Digger-wasp, 86, 260.
Diptera, 83.
Dobson, 77, 153.
Dog-day-harvest-fly, 218.
Dog-fleas, 84.
Dolomedes, 229.
Dragon-flies, 65, 89, 93.
Drosophila, 185.
Dytiscidæ, 116.

Ears, 19.
Earwigs, 69.
Elytra, 43.
Engraver-beetles, 216.
Ensign-fly, 86.
Epargyreus tityrus, 202.
Ephemerida, 64.
Estigmene acræa, 240.
Eugonia j-album, 253.
Eumenes fraternus, 259.
Eumenidæ, 258.
Euplexoptera, 69.
Eurypelma hentzii, 231.
Euvanessa antiopa, 252.
Eyes, 12.
Eyprepia, 241.

Fall web-worm, 200.
Femur, 15.
Fireflies, 335.
Fish-moths, 63.
Fleas, 84.
Flies, 83.
Folded papers for butterflies, 287.
Forceps, 299.
Forest life, 186.
Four-footed butterflies, 247.
Fritillaries, 250.
Funnel-web weavers, 222.

Galgulidæ, 160.
Gall-gnats, 162.
Gall-insects, 210.
Galls, 210.
Gelechia gallæsolidaginis, 274.
Giant silkworm, 187.
Giant water-bugs, 130.
Gills, 54.
Goldenrod, 272.
Goldenrod-galls, 274.
Gossamer-winged butterflies, 164, 246.
Grandfather graybeards, 56, 232.
Grasshoppers, 70, 233.
Grass-spider, 224.
Grouse-locusts, 164.
Gryllidæ, 74.
Gyrinidæ, 114.

Hair-streaks, 247.
Halictus, 267.
Harlequin milkweed-caterpillar, 241.
Harvestmen, 56, 232.
Head, 12.
Hemiptera, 75.
Heteroptera, 76.
Hexapoda, 53, 58.
Hollyhock, 257.
Homoptera, 77.
Honey-bee, 255.
Honey-dew, 177.
Horned corydalis, 153.
Hydrobatidæ, 109.
Hymenoptera, 85.
Hyphantria cunea, 200.
Hypopharynx, 14.

Ichneumon-fly, 86.
Ichneumonidæ, 217.
Ichthyura, 201.
Imago, 40.
Imperial-moth, 197.
Incomplete metamorphosis, 35, 37.
Inflating larvæ, 301.
Insects, 58.
Io-moth, 189.
Iphiclides ajax, 244.
Iron frame for mold for cases, 312.
Isabella tiger-moth, 240.
Isoptera, 67.

Jasoniades glaucus, 243.
Jumping spiders, 229.

Katydids, 73, 239.
Killing bottles, 285.

Labeling specimens, 315.
Labial palpi, 14.
Labium, 14.
Labrum, 13.
Lace-winged flies, 179.
Lady-bugs, 179, 180.
Lampyridæ, 273.
Larva, 40.
Lasiocampidæ, 171.
Leaf-eating caterpillars, 172, 187.
Leaf-cutter bees, 265.
Leaf-miners, 208.
Leaf-rollers, 206.
Lepidoptera, 80.
Lice, 75, 76.
Lights, 293.
Lobsters, 53.
Locust-borer, 273.
Locustidæ, 72.
Locusts, 72, 233, 236.
Long-horned beetles, 215.
Long-horned grasshoppers, 73.
Luna-moth, 192.
Lycænidæ, 164, 246.
Lycosa, 229.

Mallophaga, 69.
Mandibles, 13.
Mantidæ, 71.
Maxillæ, 13.
Maxillary palpi, 14.
May-flies, 64, 99, 101, 148.
Meadow-browns, 253.
Meadow grasshoppers, 73.
Measuring-worms, 174.
Mecoptera, 78.
Megachile, 265.
Megachile acuta, 265.
Meloidæ, 273.
Membracidæ, 220, 277.
Mesothorax, 18.
Metathorax, 18.
Microscopic objects, 300.
Millers, 80.
Millipede, 57.
Miners of the plains, 268.
Mining-bees, 269.
Mining digger-wasps, 269.
Misumena vatia, 230.
Mites, 56.
Mocha-stone moth, 201.
Mold, 314.
Molting, 36.
Monarch, 249.
Monobia quadridens, 265.
Monohamus confusor, 215.
Mossy-rose-gall, 212.
Mosquitoes, 132.
Moths, 80, 81, 239, 242.
Mourning-cloak, 252.
Mouth-parts, 13.
Muscidæ, 185.

Museum pests, 314.
Myriapoda, 53, 57.

Nepa, 128.
Nest-building caterpillars, 200.
Net-building caddice-worms, 151.
Net-winged midges, 158.
Nets, 285.
Neuroptera, 77.
Nodus, 97.
Note-books, 320.
Notolophus leucostigma, 174.
Notonectidæ, 128.
Nymphalidæ, 247.
Nymphs, 35.

Oak-apples, 210.
Oberea bimaculata, 215.
Ocelli, 13.
Odonata, 65.
Œdemasia concinna, 173.
Orb-weavers, 224.
Orchard life, 166.
Orthoptera, 70.
Oven, 302.
Ovipositor, 20.

Painted beauty, 251.
Palpus, 14.
Panorpa, 78.
Papilio polyxenes, 243.
Parasita, 76.
Periodical cicada, 218.
Phasmidæ, 71.
Phymata wolffii, 274.
Phymatidæ, 274.
Physopoda, 74.
Pieridæ, 245.
Pieris rapæ, 245.
Pine-cone willow-gall, 160.
Pinning forceps, 299.
Pins, 295.
Pita-wood, 310.
Plaginotus speciosus, 215.
Plant-lice, 163, 175.
Plecoptera, 66, 147.
Pliers, 299.
Plum-curculio, 182.
Poison ivy, 29.
Polistes, 259.
Polyphemus-moth, 190.
Polystœchotes punctatus, 78.
Pomace-flies, 184.
Praying mantes, 71.
Predaceous diving-beetles, 116.
Preservation of specimens, 294.
Preservative fluids, 300.
Prionus laticollis, 215.
Promethea-moth, 193.
Prothorax, 18.
Psephenus, 153.
Psocids, 68.
Psychidæ, 204.
Pupa, 40.
Puparium, 185.
Pyrrharctia isabella, 240.

Ranatra, 128.
Red admiral, 251.
Red-humped apple-worm, 173.
Regal-moth, 199.
Relaxing insects, 305.
Rhagium lineatum, 215.
Roadside life, 221.
Root cage, 333.
Royal-moths, 197.
Running spiders, 228.

Saldidæ, 160.
Salt-marsh caterpillar, 240.
Samia californica, 196.
Samia cecropia, 195.

Saturniidæ, 189.
Scales, 49.
Scallop-shell moth, 200.
Scolytidæ, 216.
Scorpion-flies, 78.
Scorpions, 56.
Sex, indication of, 321.
Sheep-tick, 57.
Shore-bugs, 159.
Short-horned grasshoppers, 72.
Shrimps, 53.
Sialidæ, 155.
Sialis, 156.
Silver-spotted skipper, 202.
Simple eyes, 12.
Simuliidæ, 158.
Siphon, constant-level, 331.
Siphonaptera, 84.
Siricidæ, 217.
Skippers, 80, 81.
Smaller leaf-eating caterpillars, 205.
Social wasps, 259.
Soldier-beetles, 273.
Solidago, 272.
Solitary wasps, 258.
Songs of insects, 235.
Sow-bug, 54.
Spiders, 222.
Spiracles, 19.
Spreading board, 304.
Spreading insects, 303.
Spreading pin, 304.
Springtails, 63.
Stone-flies, 66, 102, 103, 146.
Stink-bugs, 76.
Subimago, 100.
Sugaring, 292.
Sumach, 261.
Supplies for pupils, 24.
Supplies for the school, 25.
Surface film of water, 104.
Swallow-tail butterflies, 242.

Tarantulas, 230.
Tarsal claws, 16.
Tarsus, 16.
Telea polyphemus, 190.
Termites, 67.
Thorax, 17.
Thread-waisted wasps, 261.
Thrips, 74.
Thysanura, 63.
Tibia, 16.
Tiger-beetles, 270.
Tiger-moths, 239.
Tiger swallow-tail, 243.
Toad-shaped bugs, 160.
Tortricids, 182, 207.
Tortricina, 182, 207.
Tracheal gills, 54, 141.
Trap-door spiders, 230.
Tree-hoppers, 219.
Trichoptera, 79, 151.
Trochanter, 15.
Tropæa luna, 192.
True grasshoppers, 73.
Trypeta solidaginis, 274.
Trypoxylon frigidum, 262.

Vanessa atalanta, 251.
Vanessa cardui, 251.
Vanessa huntera, 251.
Veins of the wings, 16.
Veliidæ, 109.
Vespa, 260.
Vespidæ, 260.
Viceroy, 249.
Virginia creeper, 29.

Wanderer, 163.
Walking sticks, 72.

Wasps, 85, 258.
Water-boatmen, 136.
Water-pennies, 153.
Water-scavenger beetles, 120.
Water-scorpions, 128.
Water-striders, 106, 109.
Water-tigers, 119.
Weevils, 184.
White-ants, 67.
White-marked tussock-moth, 174.
Whites, 245.
Whirligig-beetles, 111.
" Wigglers," 131.
Wrigglers, 131.

Yellow-bear, 240.
Yellow-necked apple-tree-worm, 173.
Yellows, 245, 246.

Zaitha, 130.
Zebra swallow-tail, 244.

THE END.